Study Report SR350 [2016]

New Zealand whole-building whole-of-life framework: Development of reference office buildings for use in early design

Brian Berg, David Dowdell and Matthew Curtis

Note: Appendices D and E of this report have been superseded by SR418 *New Zealand whole-building whole-of-life framework: LCAQuick v3.4 – a tool to help designers understand how to evaluate building environmental performance*.

Funded from the Building Research Levy

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ISSN: 1179-6197

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 under Research Stream 2 (RS2) within a programme of research to develop the framework. The aim of RS2 is to develop a set of reference office buildings that may be used as comparators during 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:

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

Dowdell, D. (2012). *Review of how life cycle assessment is used in international building environmental rating tools – issues for consideration in New Zealand*. BRANZ Study Report SR272. Judgeford, New Zealand: BRANZ Ltd.

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.

Acknowledgements

This work was funded by the Building Research Levy. Gratitude is also extended to Callaghan Innovation for provision of a research and development scholarship, which helped towards the development of *LCAQuick – Office*.

BRANZ would like to take this opportunity to thank the individuals who have been part of this project and who have kindly provided their advice, feedback, time and information:

Adam Schofield, Autex

Adrian Bennett, Ministry of Business, Innovation and Employment

Andy Anderson, Jasmax

Blair Gollop, Hawkins Construction

Chris Kay, NZ Steel (nominated representative of the Sustainable Steel Council)

Clare Gallagher, New Zealand Green Building Council

Craig Mills, Aecom (nominated representative of The Property Council New Zealand)

Daniel Scheibmair, New Zealand Timber Design Society

Jayson Fleming, Holmes Consulting

Joe Gamman, CCANZ

John McArthur, Fletcher Building

Kelvin Walls, Building Code Consultants (nominated representative of IPENZ)

Kevin Golding, Winstone Wallboards

Marc Woodbury, Studio Pacific Architecture

Mark Glenny, Resene

Matt Wilton, Hawkins Construction

Melanie Tristram, Jasmax

Michael Thomson, Architectus (nominated representative of NZIA)

Nick Carman, Holmes Consulting

Peter Jeffs, Architectus

Rolf Huber, Construction Information

Stuart Ng, Standards New Zealand

BRANZ would also like to thank Architectus, Jasmax and Holmes Consulting for kindly beta-testing an early version of *LCAQuick – Office*, The EcoInvent Centre for their co-operation and advice and Tim Grant, Director of lifecycles, for reviewing the LCA-based data in *LCAQuick – Office*.

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 design of new offices in New Zealand but may be helpful for other applications of building LCA.

Note that Appendices D and E of this report have been superseded by SR418 *New Zealand whole-building whole-of-life framework: LCAQuick v3.4 – a tool to help designers understand how to evaluate building environmental performance.*

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BRANZ Study Report SR350

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Reference

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.

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.

To help designers to understand the life cycle environmental implications of their designs based on LCA, reference office buildings have been developed to act as comparators during the design process. These reference office buildings are based on consented New Zealand buildings (that are entirely offices or largely offices) with gross floor areas exceeding 1500 m^2, located in either Auckland, Wellington or Christchurch. They have been developed for application to early design and reflect building structure and thermal envelope, as well as simulated energy use during occupation according to energy model outputs.

Generic environmental impact data for products used in the structure and thermal envelope have been developed in order to calculate environmental indicators for the reference office buildings, normalised to floor area.

These reference office buildings are embedded within the awareness raising tool *LCAQuick – Office* to provide a basis for comparison during early design.

Keywords

BIM, energy, environment, LCA, LCAQuick, life cycle analysis, life cycle assessment, office, whole building, whole of life, reference buildings

Contents

Figures

Tables

Acronyms and terms

AAC	autoclaved aerated concrete
ACM	aluminium composite material
AIA	American Institute of Architects
ALCAS	Australian Life Cycle Assessment Society (www.alcas.asn.au)
APME	Association of Plastic Manufacturers in Europe
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AusLCI	A freely available life cycle inventory database of Australian products and processes developed by ALCAS. See http://alcas.asn.au/AusLCI/.
BIM	building information model
BMT	base metal thickness (in millimetres)
BPS	building performance sketch
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).
building performance sketch	A simplified quality assured model or simulation of a specific area of building performance that is developed to have sufficient (but not excessive) detail and tailored to provide a meaningful level of information for decision-making purposes during early design.
CAENZ	New Zealand Centre for Advanced Engineering
CCANZ	Cement and Concrete Association of New Zealand
CHS	circular hollow section
CIBSE	Chartered Institution of Building Services Engineers
CLT	cross-laminated timber
Co	Commercial office activity classification (used in BEES and obtained from the PropertyIQ valuation roll). Used for buildings that are entirely offices.
CV(RMSE)	Coefficient of variation of root-mean squared error. A measure of calibration tolerance for operational energy use defined in ASHRAE Guideline 14:2002.
Cx	Commercial office mixed classification used in BEES and obtained from the PropertyIQ valuation roll. Used for buildings that are primarily offices but contain other uses (for example, a gym or café).
DOCf	degradable organic fraction
DOE	(US) Department of Energy
EcoInvent	A proprietary database of materials and processes for use in LCA, developed and maintained by The EcoInvent Centre, Switzerland. See www.ecoinvent.org.
EE	embodied energy
embodied	Total of an environmental indicator attributed to manufacture. For example, embodied energy refers to the sum total of energy needed from extraction of resources through to manufacture of a final product. Similarly, embodied carbon refers to the total of greenhouse gas emissions from extraction of resources through to manufacture of a final product. Sometimes may also include transport to the construction site and installation.
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.

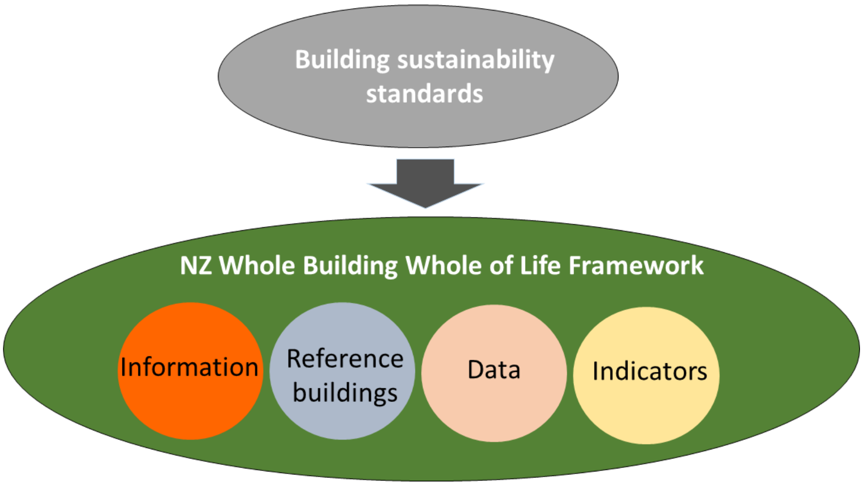
EPD	environmental product declaration
EPDM	ethylene propylene diene monomer (synthetic rubber)
EPS	expanded polystyrene
FWPA	Forest and Wood Products Australia
GFA	gross floor area – usually measured in square metres (m^2)
GGBS	ground granulated blast furnace slag
GJ	gigajoules (1 GJ = 1,000,000,000 joules)
glulam	glued laminated timber
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	Area measured over all the exterior walls of the building, over partitions, columns, interior structural or party walls, stair wells, lift wells, ducts, enclosed roof top structures and basement service areas. All exposed areas such as balconies, terraces, open floor areas and the like are excluded. Generally, projections beyond the outer face of the exterior walls of a building such as projecting columns, floor slabs, beams, sunshades and the like are excluded (NZIQS, 2012).
GWP	global warming potential
HVAC	heating, ventilation and air conditioning.
IBU	Institut Bauen und Umwelt – a German EPD programme operator for construction
ICE database	Inventory of Carbon & Energy – a database of embodied energy and carbon for a range of UK construction materials
IDP	integrated design process
IEA	International Energy Agency
kWh	kilowatt hour
LCA	life cycle assessment
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. Performs an evaluation of a design and compares it to one or more reference New Zealand office buildings.
LCI	life cycle inventory
LDPE	low-density polyethylene
level of development	Term used in BIM to indicate to users the level of resolution of a BIM object. It conveys the degree to which the element's geometry and attached information has been thought through and the degree to which project team members may rely on the information when using the model (BIMForum, 2013).
life cycle assessment	Compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (ISO, 2006).
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, 2006).
LOD	level of development
LVL	laminated veneer lumber
MAF	Ministry of Agriculture and Forestry (now part of the Ministry for Primary Industries)

MBE	mean bias error – a measure of calibration tolerance for operational energy use defined in ASHRAE Guideline 14:2002
MBIE	Ministry of Business, Innovation and Employment (www.mbie.govt.nz)
MfE	Ministry for the Environment (www.mfe.govt.nz)
module	Discrete part of the building life cycle that encompasses all the processes that occur. For example, modules A1, A2 and A3 cover production of materials whilst module B6 covers operational energy use in a building. The modules in the life cycle of a building are set out in EN 15978 (CEN, 2011), and further information is provided in BRANZ Study Report SR349 (Dowdell & Berg, 2016).
MPa	megapascals
MRF	municipal recycling facility
M&V	measurement and verification – a guideline published by the US Department of Energy
net lettable 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). Usually measured in square metres (m^2).
NGA	National Greenhouse Accounts
NLA	net lettable area
NZBC	New Zealand Building Code
NZCIC	New Zealand Construction Industry Council (www.nzcic.co.nz)
NZGBC	New Zealand Green Building Council (www.nzgbc.org.nz)
NZIQS	New Zealand Institute of Quantity Surveyors (www.nziqs.co.nz)
ODP	ozone depletion potential
OPC	ordinary Portland cement
PCR	product category rule
PE	polyethylene
PET	polyethylene terephthalate
PFA	pulverised fuel ash
ppm	parts per million
product category rules	Set of specific rules, requirements and guidelines for developing Type III environmental declarations [or EPDs] for one or more product categories (ISO, 2010).
PV	photovoltaic
PVC	polyvinyl chloride
RIBA	Royal Institute of British Architects
RS	research stream (within the New Zealand whole-building whole-of-life framework research)
RoW	rest of the world
SDS	(material) safety data sheet
SoQ	schedule of quantities (as developed by a quantity surveyor or produced from BIM)
WEERS	Window Energy Efficiency Rating System provided by the Window Association of New Zealand
XPS	extruded polystyrene
UB	universal beam
VAV	variable air volume (type of HVAC system)
VOC	volatile organic compound

1. Executive summary

BRANZ, with industry and research partners, has developed the New Zealand whole-building whole-of-life 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.

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



This report sets out the research undertaken to develop a set of 10 reference New Zealand office buildings modelled to a level of detail and quality assured for use as comparators during early (concept and preliminary) design.

The reference office buildings are post-2005 consented office buildings in Auckland, Wellington and Christchurch, representing a range of sizes above 1500 m^2 gross floor area (GFA), activities (only office and primarily office with other activities) and structural systems. The reference buildings are not a statistically representative sample of New Zealand office buildings but are examples of recent office buildings that have been consented and built.

The reference office buildings have been modelled based on consent documentation. They represent materials used in the structure and thermal envelope and simulated energy use, based on early design stage information.

In order to develop the reference office buildings, the following tasks were completed:

1. An analysis was carried out of materials use in elements of newly consented office buildings, using findings from the BRANZ non-residential survey.
2. A list of potential office buildings was compiled from consent records and compared to the analysis from step 1 above in terms of building structure and thermal envelope. The list was informed by this analysis only to ensure that alternative materials not currently used at volume were also included (for example, office buildings with engineered wood or timber structures).
3. Consent documentation was obtained from local authorities. Where possible, architects involved in the design of an office building were invited to submit information and a building information model (BIM) with their client's consent.
4. A BIM model for each building was developed and quality assured to produce accurate material quantities (for the structure and thermal envelope of the

building). This represents the materials used in the building according to the consent documentation and specification.

5. An energy model for each building was developed, based on typical energy use according to findings of the Building Energy End-use Study (BEES) research, taking into account the building's location, form, orientation, window to wall ratios, structure and thermal envelope materials and activities by building occupants. BEES energy model templates were used to more closely reflect the likely 'real' energy use in the building resulting from its design, according to measured energy use in BEES office buildings.
6. Environmental impacts were calculated for different materials (used in the structure and thermal envelope of office buildings) for different life cycle stages covering manufacture, transport and installation, maintenance, replacement and end of life, plus potential benefits and loads beyond the building life cycle. Environmental impacts were also calculated as a result of use of low-voltage grid electricity in office buildings.
7. Development of a resource for calculating building environmental impacts based on the outputs of steps 4, 5 and 6 above, which can also be used for assessment of alternatives. This resulted in *LCAQuick – Office*, a free resource aimed at helping design team professionals become more familiar with LCA and how to use it in the design process.
8. A schedule of quantities (SoQ) from each BIM model and results of energy modelling were imported into *LCAQuick – Office* (which contains environmental impact data from step 6) in order to calculate potential environmental impacts over the life of each of the reference buildings.

Environmental indicator values for the reference office buildings are provided in this report. The buildings are also embedded in *LCAQuick – Office* (available at www.branz.co.nz/buildingLCA), where they can be used as a basis for comparison during early building design.

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 that, 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:

- It provides more of a level playing field for assessment, with a focus on environmental performance of buildings across the life cycle.
- It enables evaluation of the environmental performance of buildings according to their function.
- It 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.
- It aligns with ongoing developments in building environmental assessment according to international standards.
- It 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.
- It 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.
- It facilitates a stronger connection between supply and demand for construction products. Architects and designers who 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 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 BIM objects freely downloadable for 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 *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 aim of the framework 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 Study Report SR293 (Dowdell, 2014). The report sets out current environmental indicators for reporting and environmental indicators highlighted for future incorporation into the framework. The report includes calculation methodologies and characterisation factors for use in calculating 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 this study report (SR350).
- *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, with supporting information in study report SR351 (Dowdell et al, 2016). Whilst the information has been developed for application to early-stage design, it may also be useful for other building LCA applications.

These study reports and resources can be downloaded from the BRANZ website at www.branz.co.nz/buildingLCA.

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.

- Development of characterisation factors and evaluation to facilitate the calculation of 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 are 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 and how to use it
- 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 can contribute to potential 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 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 basis for the reference office buildings that have been developed as part of the framework and why they have been developed.
- Section 4 provides an analysis of New Zealand office buildings based on BRANZ surveys.
- Section 5 sets out the methodology and quality assurance testing undertaken during development of the reference buildings.
- Section 6 provides environmental indicator results for the reference office buildings.

3. Basis and development of reference office buildings

3.1 Basis

The floor area of new office/administration buildings consented in New Zealand between 2008 and 2012 exceeded 1 million m^2 with a value in excess of \$2.6 billion (Table 1).

Table 1. New office/administration building consents in New Zealand 2008–2012.[1]

Year	Number	Value (NZ$)	Floor area (m^2)
2012	301	470,675,307	226,843
2011	294	302,781,952	195,363
2010	273	298,608,011	158,313
2009	254	861,424,701	273,982
2008	380	686,823,740	380,365
Total	**1,502**	**2,620,313,711**	**1,234,866**

Research undertaken for the Building Energy End-use Study (BEES) identified that there is no comprehensive New Zealand list of commercial buildings (Isaacs et al., 2009). In response, a non-residential stratification by floor area was developed based on records from the PropertyIQ valuation roll for New Zealand, reproduced in Table 2.

Table 2. Non-residential size strata (Isaacs et al., 2009).

Floor area group	1	2	3	4	5	Total
Minimum floor area (m^2)	5	650	1,500	3,500	9,000	
Approximate number of buildings	33,781	10,081	4,288	1,825	564	50,539
% of buildings	67	20	8	4	1	100
Total floor area (million m^2)	9.9	9.6	9.5	9.6	9.8	48.3
% floor	20	20	20	20	20	100

This was used within the BEES research for determining equal sample sizes for each of the five size groups. The size classes from Table 2 have been used as the basis by which reference office buildings have been categorised in this work.

Within these size groups, the reference buildings have been further categorised by building use, location and structure. Further information on this categorisation is provided in section 5.1.

[1] Values include GST. From 1 September 1989, consents below \$5,000 are excluded. For staged consents, values are recorded at each stage, but floor areas and unit counts are normally recorded at the first large stage. Includes garages, glasshouses and sheds on residential sections. Alterations and additions are included.

3.2 Development

The purpose of developing reference office buildings is to provide a basis for comparison during design. Since the scope of research carried out is focused on concept and preliminary design, reference buildings have been developed to a level of detail suitable for these stages in the design process (respecting that exactly what is included in concept and preliminary design, as opposed to other stages of design, may not be the same from one design team to another).

Thus, by having reference buildings for which life cycle environmental impacts are calculated, design teams have an opportunity to use these to compare their own early designs and to assess the environmental implications of alternative design choices.

Ideally, as with the BEES research, reference office buildings would be statistically representative of new office buildings in New Zealand. This representativeness would need to encompass not just energy use but also the typical amounts and types of materials used in buildings. Having determined what would be considered statistically representative, either an actual building or buildings that meet 'typical' criteria for energy and materials would need to be found, or prototypical building models would need to be developed, i.e. models of buildings that do not actually exist in New Zealand but are based on typical energy use and materials composition.

No comprehensive dataset is available in New Zealand on materials types and quantity used in office buildings. BRANZ collects some data on materials use in consented buildings (see section 4), but this dataset is not statistically representative. To develop such a dataset was considered prohibitive in terms of scale and cost.

Therefore, an approach was used to derive a set of references that provide examples of actual materials used in consented built New Zealand office buildings, with simulated energy use according to the early design characteristics of the building. The process that was followed is set out below.

1. An analysis was carried out of materials use in elements of newly consented office buildings, using findings from the BRANZ non-residential survey. This was used as a guide only. The findings of this analysis are provided in section 4.
2. A list of potential office buildings was compiled from consent records and compared to the analysis from step 1 above in terms of building structure and thermal envelope. The list was informed by this analysis only and expanded to include other materials not currently used at volume in office developments (for example, engineered wood structures).
3. Consent documentation was obtained from local authorities. Where possible, architects involved in the design of a selected building were invited to submit information with their client's consent.
4. A BIM model for each building was developed and quality assured to produce accurate material quantities (for the structure and thermal envelope of the building). This was used to produce a schedule of quantities (SoQ) of materials used according to the consent documentation and specification. Further information about this is available in section 5.3.1.
5. An energy model for each building was developed, using office energy template models developed as an output of the BEES research,[2] taking into account the building's location, form, orientation, window to wall ratios on each side, materials

[2] www.branz.co.nz/cms_display.php?sn=158&st=1&pg=14879

use and activities by building occupants. This was used to more closely reflect the likely 'real; energy use in the building resulting from its design, according to measured energy use in BEES office buildings (see section 5.3.2).

6. Environmental impacts were calculated for structure and thermal envelope materials used in office buildings for different life cycle stages covering manufacture, transport and installation, maintenance, replacement and end of life, plus potential benefits and loads beyond the building life cycle (see section 0).
7. Development of a resource for calculating building environmental impacts based on outputs of steps 4, 5 and 6 above, which can also be used for assessment of alternatives. This resulted in *LCAQuick – Office*, a free resource with the aim of helping design team professionals better understand how to use building LCA in design (see section 5.3.4).
8. SoQs from step 5 and energy modelling results from step 6 were imported into *LCAQuick – Office* in order to calculate potential environmental impacts over the life of the building.

The reference buildings therefore provide examples of offices that have been consented and built in New Zealand recently. The energy use calculation does not reflect real energy use in these buildings (which has not been measured) but reflects the simulated energy use based on what has previously been measured for New Zealand office buildings in the BEES project. Use of the BEES energy modelling defaults aims to reduce as far as possible the performance gap between simulated energy use during early design and post-occupancy energy use.

The reference office buildings should not be considered as statistically representative of New Zealand office buildings. They provide recent examples, some of which achieved higher environmental performance as assessed using the New Zealand Green Building Council's Green Star building environmental rating tool.

During 2016, Green Star incorporated a building LCA Innovation Challenge. Reference buildings developed for this work have not been produced specifically for the purpose of a comparative assessment in Green Star. Selection and use of an appropriate reference building for the purpose of obtaining building LCA Innovation Challenge points should be agreed with the New Zealand Green Building Council.

4. Office buildings according to BRANZ survey results

This section provides a summary of an analysis carried out on results of an annual BRANZ non-residential survey completed by builders and designers.

4.1 Method of assessment

Whilst the building consents listed in Table 1 provide an overview of building consent activity, they do not provide any information about specific building consents, needed to select potential reference buildings, nor do they provide any information on the products proposed for use in consented buildings.

More detailed data on building consents was also obtained from Whats On (www.whatson.co.nz) for new commercial buildings over the same period shown in Table 1. The Whats On data provided information such as building consent number, local authority, issue date, description of works, floor area, value and address. Whilst the data provides more detail, it is a smaller dataset in comparison with the Statistics New Zealand data from which Table 1 has been developed, comprising 37% of office/administration building consents by number and value and 54% by floor area. The dataset also contains no information about materials used in buildings.

BRANZ began surveying builders and designers in 1998 to obtain data on materials used in buildings, which has resulted in the compilation of a database of approximately 400 non-residential buildings per year containing information on materials used by building component (Curtis, 2015). The survey consists of questions, each with a number of choices from which the individual completing the survey ticks those that are applicable. Questions may also contain an 'other' category where the respondent also has room to provide more detail, although this is not always provided.

Information about the physical characteristics of new office buildings was extracted from this database for the period 2008–12. This amounted to 97 buildings, being nearly 7% of total office/administration building consents over the period.

An assessment of materials used in different elements in these 97 buildings was undertaken, with results presented by the five size groups (quintiles) in Table 2, originally developed for BEES (Isaacs et al., 2009).

The analysis presented below presents revealed trends in materials use for offices by floor area ranges. Matching the BRANZ survey data to Whats On consent data also provided an opportunity to identify potential reference office buildings. The data allows estimates of the incidence and proportions of different materials to be made.

This analysis provides a guide as to the types and incidence of materials that have historically been consented during the period 2008–12. It does not necessarily reflect all materials that may have been used during the period. There may be numerous office buildings that have been constructed during this period that may use materials that are not specifically covered.

The number of buildings making up the larger quintiles (i.e. office buildings that are greater than 1500 m^2) is low, so results should be used with caution.

4.1.1 Analysis of materials used in office buildings

The analysis in this section is divided into the following building elements:

- Structure
- Cladding
- Framing
- Floors.

Structure

Figure 1 provides a breakdown of the main structural materials used in the office buildings that were surveyed. The use of a concrete frame increases with the floor area of the building. The proportion of offices with a steel frame varies between 36% and 52% across all floor areas. Use of other structural alternatives (which includes timber, tilt slabs and concrete blocks) reduces as the size of office buildings increases.

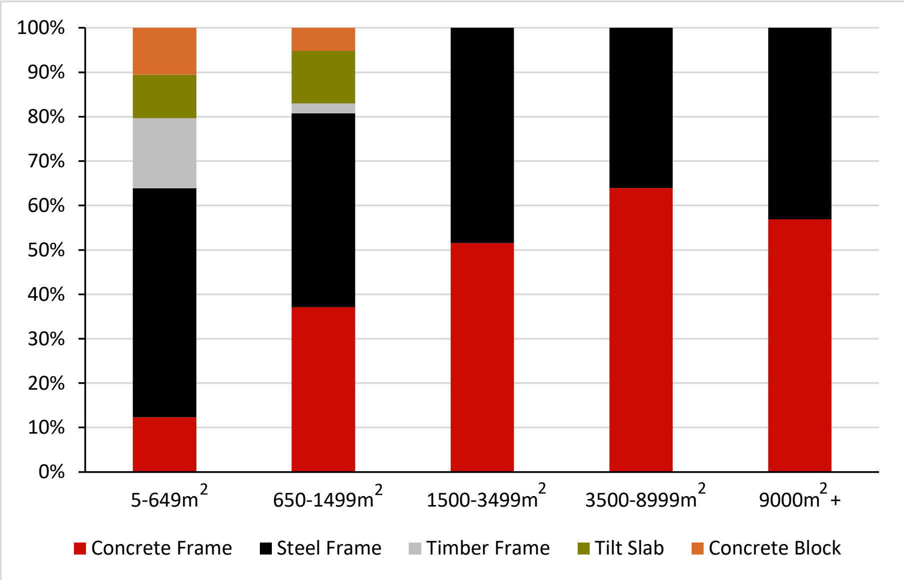


Figure 1. Structures found in surveyed office buildings.

Data on the roof structure for office buildings is limited. The question on the roof structural material was inserted into the survey in May 2011, and therefore there is less data to draw information from than for other components.

Figure 2 shows that steel is the dominant roof structure for office buildings, particularly for buildings with larger floor areas (although no data was available for the largest floor area). Timber has a strong share in the smallest size quintile, but this share abates as the building size increases.

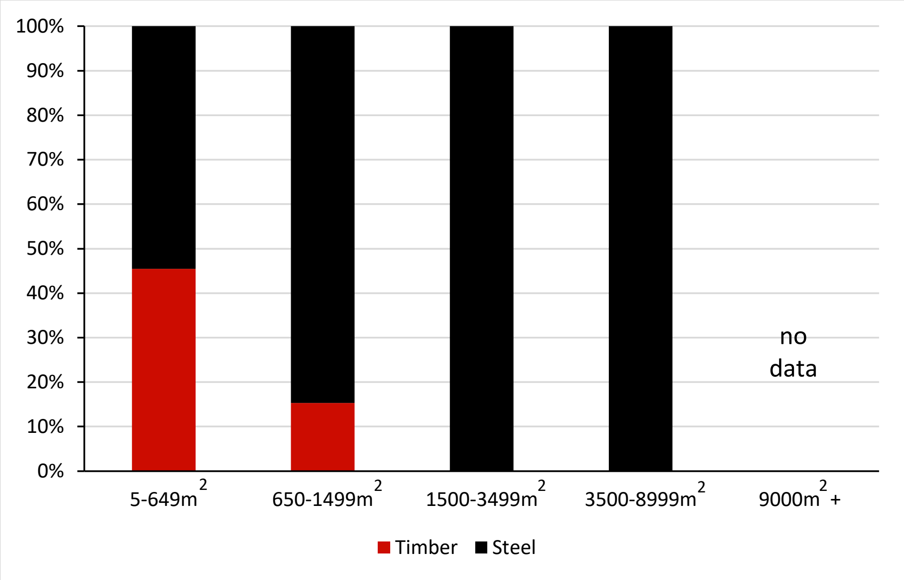


Figure 2. Roof structure found in surveyed office buildings.

Cladding

Due to the variety of claddings available, Figure 3 shows claddings by material type. Sheet metals appears to be more common in office buildings with less than a 3,500 m^2 floor area. Fibre-cement, comprising almost one-third of claddings in the smallest size group, makes up only a small proportion or is not found in other size groups.

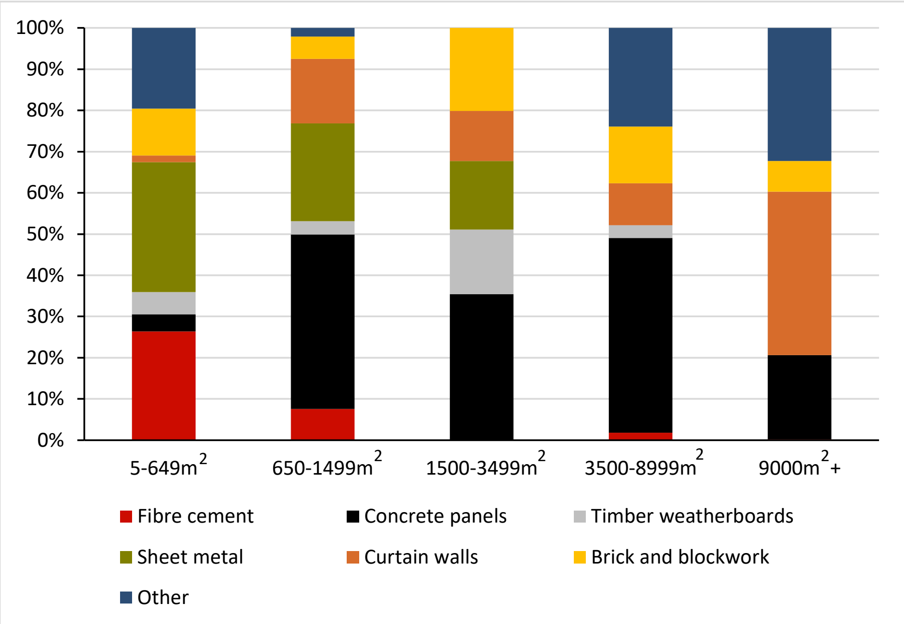


Figure 3. Wall claddings found in surveyed office buildings.

Concrete panels contribute the largest share of claddings in office buildings with a floor area between 650 m^2 and 9,000 m^2. They also provide more than 20% of claddings used in office buildings with a floor area above 9,000 m^2. This largest size group is dominated by curtain walls, which comprise around 40%.

There is also a large proportion of ‘other’ claddings in office buildings with a floor area above 9,000 m^2. No information concerning this was provided but is believed to comprise primarily of glazing and composite panels.

Figure 4 summarises roofing materials found in office buildings. Sheet metal is the most common roof cladding material for office buildings. It is almost completely dominant in office buildings less than 3,500 m^2. In office buildings that are greater than 9,000 m^2, bitumen sheet is about as common as sheet metal.

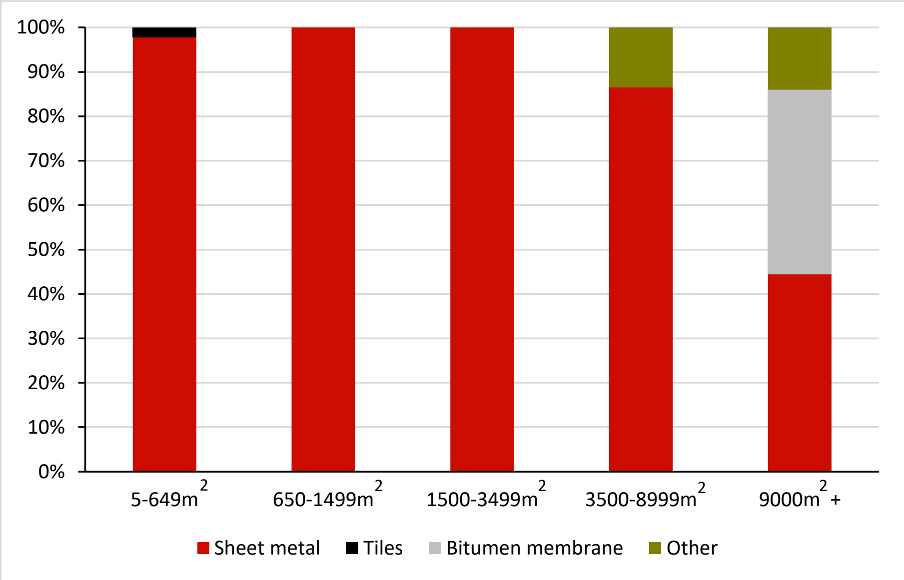


Figure 4. Roof claddings found in surveyed office buildings.

Framing

Figure 5 shows timber, steel and concrete framing is present in all size groups. Timber is commonly used for partition wall framing irrespective of office floor area, although has a markedly lower share in office buildings with floor areas above 1,500 m^2. Use of steel framing in partition walls has a similarly large share in office buildings with floor areas over 9,000 m^2 and 1,500–3,499 m^2. Almost all the balance comprises concrete.

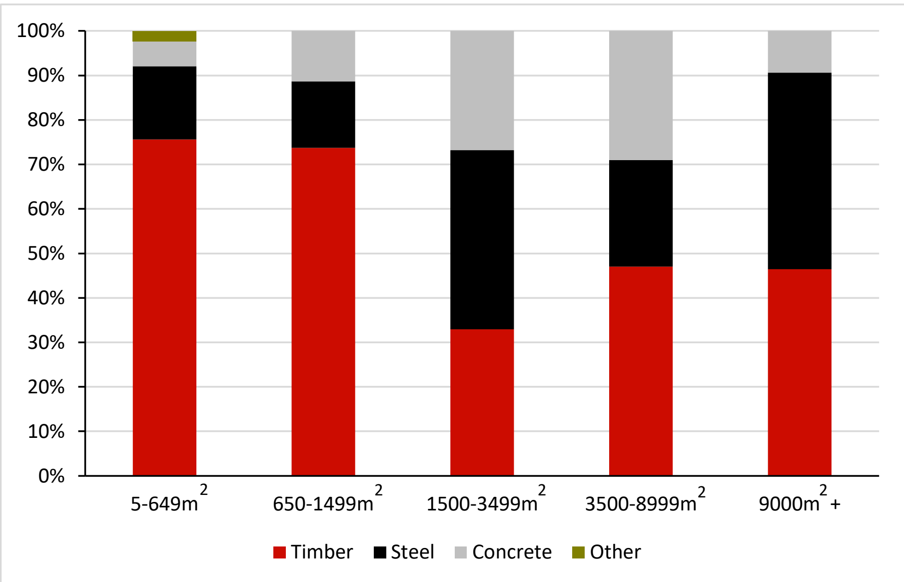


Figure 5. Partition wall framing found in surveyed office buildings.

Figure 6 summarises the materials used in wall infill framing in surveyed office buildings. There does not appear to be a clear trend concerning which materials are used between the different size quintiles. Radiata pine has a significant share, particularly in office buildings with a floor area less than 1,500 m^2. Steel framing also has a large share across all size categories.

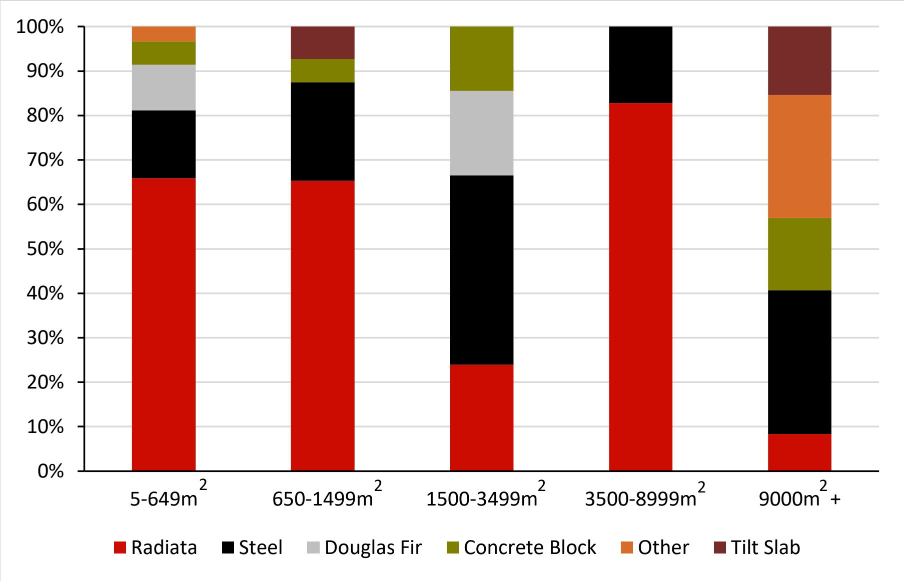


Figure 6. Wall infill framing found in surveyed office buildings.

Floors

Concrete is the dominant flooring material across all size groups, as shown in Figure 7. Only in the smallest size class comprising offices with a floor area less than 650 m^2 do other flooring materials such as particleboard and plywood make a discernible contribution.

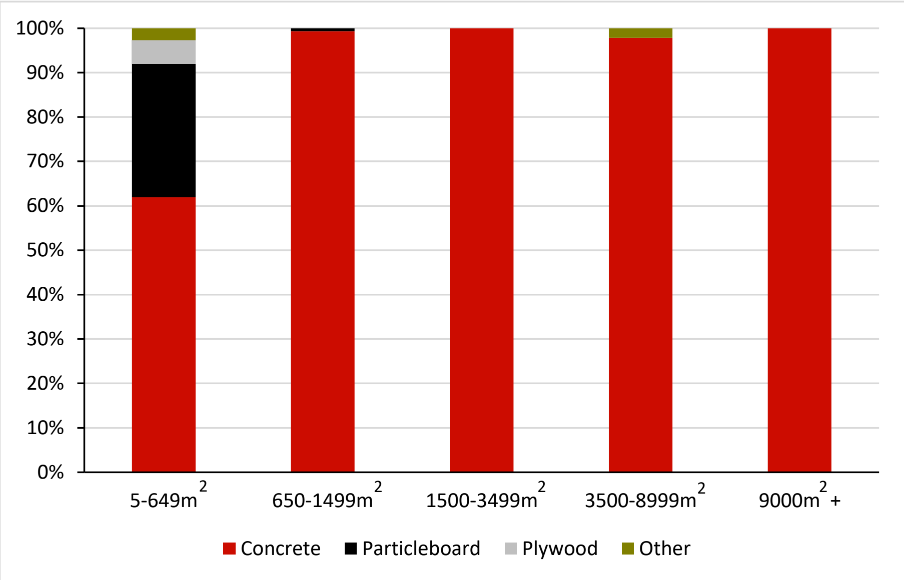


Figure 7. Floor materials found in surveyed office buildings.

5. Reference buildings development

Currently, there appears to be little published research concerning the definition of a reference or benchmark building for use in LCA or what it must encompass. The default stance appears to be that building models should be to a level of detail that is as high as possible. This gives no consideration to the time it can take to develop building models, how complete the assessment is or how trustworthy the results are.

As part of the whole-building whole-of-life framework research, 10 reference office buildings were developed in order to provide a basis for comparison during early design. The level of detail required to obtain reasonable outputs for early design decisions has been tested.

The results of these 10 reference office buildings are embedded in *LCAQuick – Office,* an awareness-raising tool developed by BRANZ with the aim of helping design professionals better understand what LCA is and how to use it (see the BRANZ Study Report SR349 (Dowdell & Berg, 2016) for more information).

It is important to understand the distinction between a reference and a benchmark. The term 'benchmark' infers statistical representation of a larger sample, whereas a 'reference' is a specific case and is not statistically representative of a larger sample. Therefore, reference buildings developed for this work provide examples of post-2005 consented office buildings in New Zealand. Development of benchmark buildings was not possible due to data availability and the scope of such a project.

5.1 Classification

It is useful to consider specific reference buildings in the context of a broader classification to facilitate meaningful comparison. A review of published whole-building life cycle energy use research case studies by Yung, Lam and Yu (2013) resulted in formulation of a database of published results, organised according to the following:

- Published building area – this could be any of built-up area, gross floor area, gross floor internal area, gross external floor area, habitable area, heated area, living area, total floor area or usable floor area.
- Building location, i.e. country.
- Building's main structural system and main structural material.
- Building type, i.e. industrial, office, residential or university.

These provide a basis for the building classification system used in this work, set out in more detail in the following sections and summarised in Figure 9.

5.1.1 Location

NZS 4243.1 (Standards New Zealand, 2007) divides New Zealand into three separate zones:

- Zone 1: Northland, Auckland Franklin District and the Coromandel Peninsula.
- Zone 2: The North Island except the Central Plateau.
- Zone 3: The Central Plateau of the North Island and all of the South Island.

This provides a parameter for classifying reference buildings by their climate zone. Each building is simulated for the climate zone in which it is physically located and for each of the other two climate zones.

5.1.2 Activity

Previous research on energy use in commercial buildings used property category codes according to main activity, derived from the PropertyIQ valuation roll for New Zealand – see BRANZ Study Report SR224 (Isaacs et al., 2009). Within the scope of this research, building activities selected for reference building development have been limited to Commercial office (Co) and Commercial office mixed (Cx). When a building is classified as Co, its use is solely as an office, whereas a Cx classification means there may be a number of different activities in the one building (although its primary function is as an office).

These and other classifications by activity from BRANZ Study Report SR224 are reproduced in Table 3.

Table 3. Summary of building classifications by activity (Isaacs et al., 2009).

Valuation record		Building use strata	
Code	Description	Code	Description
CO	Office-type use	CO	Commercial Office
CR	Retailing use	CR	Commercial Retail
CL	Liquor outlets including taverns etc.		
CM	Motor vehicle sales, service etc.		
CS	Service stations		
CT	Tourist-type attractions and non-sporting amenities		
CV	Vacant land when developed will have a commercial use		
CX	Other commercial uses or where there are multiple uses	CX	Commercial Other
IS	Service industrial, direct interface with the general public	IS	Industrial Service
IW	Warehousing with or without associated retailing	IW	Industrial Warehouse

5.1.3 Size

BEES additionally divided commercial buildings into five size ranges (called strata) according to floor area (Isaacs et al., 2009). Details of these size strata are shown in Table 2.

For the purposes of this project, reference buildings have been developed and categorised using size classes that match the floor area ranges in the BEES size strata. This is limited to size classes 3, 4 and 5 only.

5.1.4 Structure

Berg (2014) summarised embodied energy results for structural materials from published literature (Figure 8).[3] Embodied energy is a calculation of the energy required to produce a material that is therefore 'embodied' in it. Embodied energy may be used as an indicator of environmental impact but has two key limitations:

[3] The figure also contains an average embodied energy derived by Yung, Lam and Yu (2013) for comparison.

- It is a measure of energy use rather than the impact of that energy use. There is no distinction between the sources of energy, which may be from renewables or fossil fuels with quite different associated environmental impacts.
- It does not consider energy use and associated impacts across the building life cycle, including operational use of energy. Put simply, a building with more insulation in it will have higher embodied energy compared to an identical building without insulation. However, the building with insulation is likely to have a lower operational energy requirement, which is not considered in an embodied energy calculation.

In this work, embodied energy is similar to total primary energy (from BRANZ Study Report SR293 [Dowdell, 2014]) in modules A1–A3 of the product stage of the building life cycle (from BRANZ Study Report SR349 [Dowdell & Berg, 2016]).

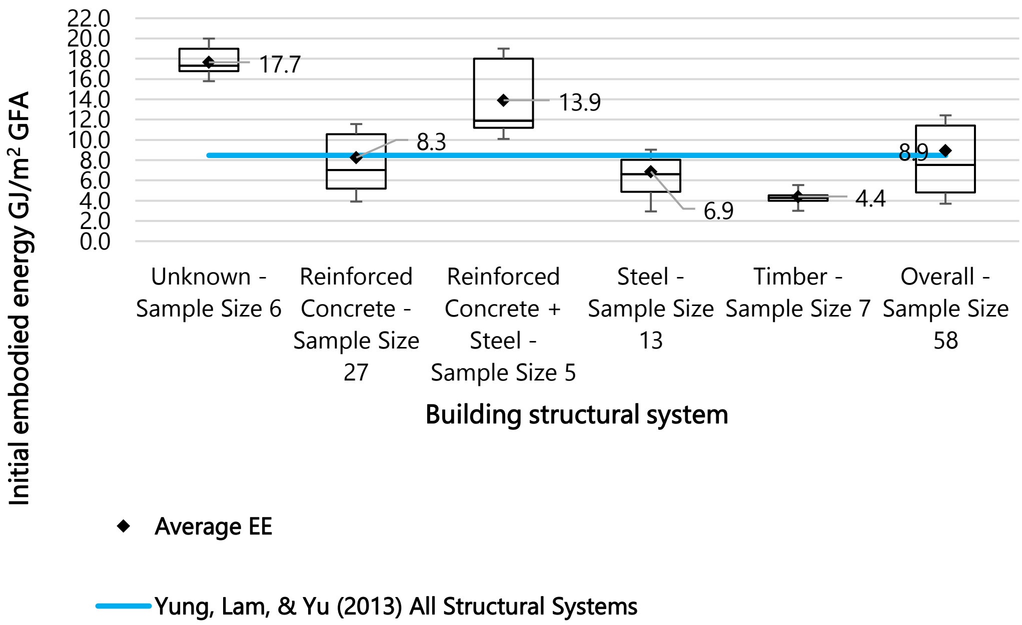


Figure 8. Summary of embodied energies (EE) of office buildings by structural system (Berg, 2014).

Commercial buildings may comprise different structural materials and different structural systems. In terms of materials, Gunel and Ilgin (2007) used the following distinctions (which did not include structures based on timber):

- Reinforced concrete refers to beams, columns and shear walls made of reinforced concrete.
- Steel refers to beams, columns and bracing made of steel.
- Composite refers to all combinations of steel and reinforced concrete elements.

It is also common practice to classify a building's structural system based on its resistance to lateral loads as opposed to vertical loads (Ali & Moon, 2007; Gunel & Ilgin, 2007). Gunel and Ilgin (2007) divided structural systems into six categories:

- Rigid frame systems
- Braced frame and shear-walled frame systems

- Outrigger systems
- Framed-tube systems
- Braced-tube systems
- Bundled-tube systems.

A detailed description of structural systems by Gunel and Ilgin (2007) is in Appendix A.

Cross-laminated timber (CLT) and post-tensioned timber frame are two types of timber-based structures increasing in prevalence within the New Zealand construction industry (Iqbal, 2015; Newcombe, 2011), along with the traditional post/column and beam or stud framing systems used in NZS 3604 (Standards New Zealand, 2011). A description of these types of structural systems is also provided in Appendix A.

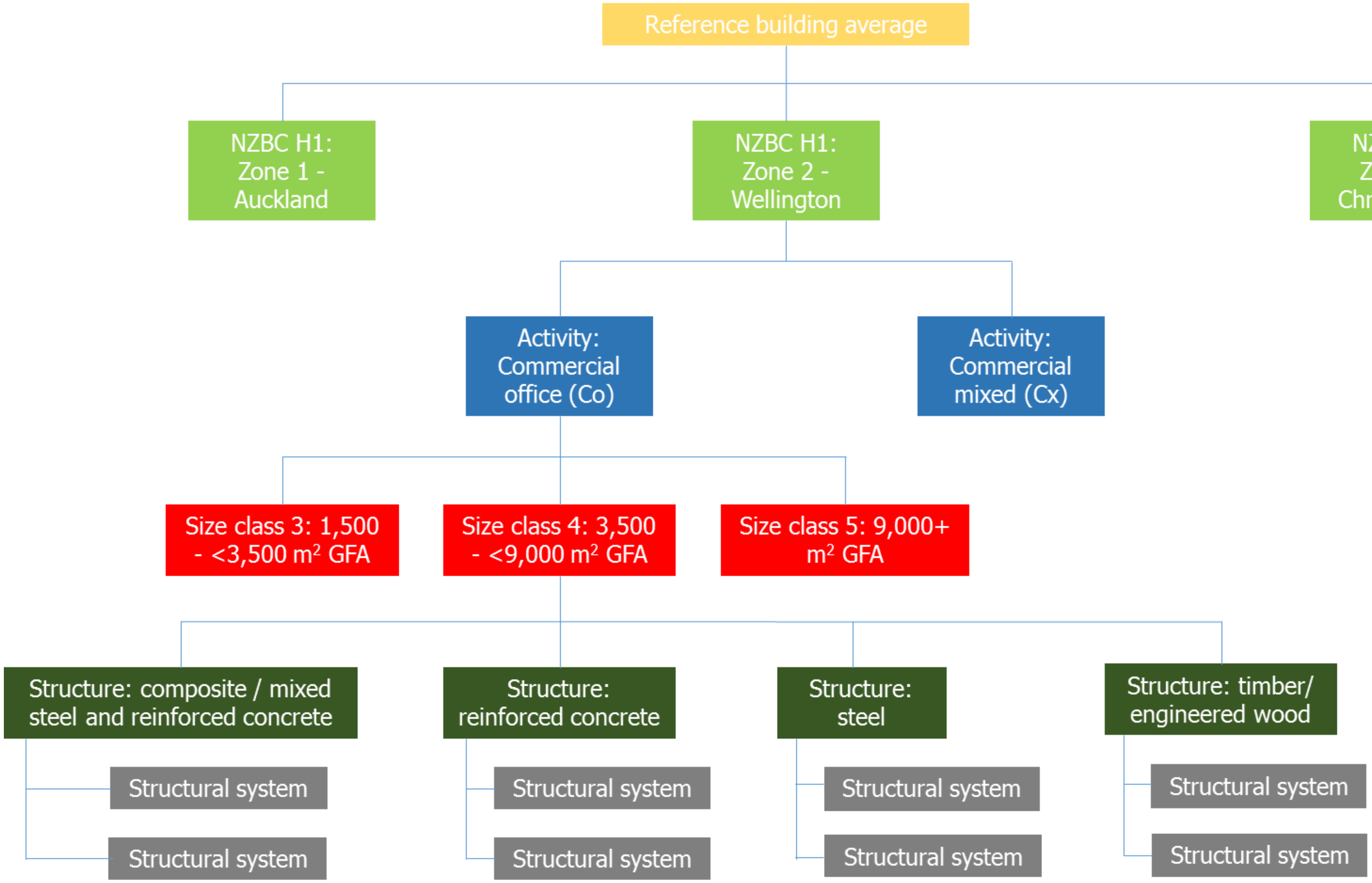


Figure 9. Reference building classification system.

5.2 Application to early design

Reference buildings developed for this work are intended to provide a basis for comparison during the early stages of design (concept and preliminary design). They are based on the concept of a building performance sketch[4] (Donn, Selkowitz & Bordass, 2012) and aim to inform early design decisions that, once made, cannot be easily altered in later design phases. These include decisions about the orientation, massing and other potential passive design solutions of a building, window to wall ratios and its structural and thermal envelope.

Early design sketch models are, by necessity, less detailed due to the level of information available. In terms of modelling buildings using BIM, this means that the level of development (LOD) of BIM objects used in BIM is at a lower resolution and requires less modelling time (assuming the BIM objects cannot be downloaded from a manufacturer's website, for example).

It is therefore useful to obtain a sense of the implication of using simplified materials information for calculating building environmental impacts in comparison with more complete information available at detailed design. This assessment was based on a method used by Berg (2014).

An Auckland office building was modelled using BIM at a concept level. Focus was only on the building's structure and thermal envelope. BIM objects used in the model were at an LOD of 200 to 300, depending on the materials being considered. A schedule of quantities was produced from this model from which environmental impacts were calculated using *LCAQuick – Office*. This was then compared to a schedule of quantities for the same building produced at detailed design by a quantity surveyor, from which quantities for the structure and thermal envelope were extracted. Again, environmental impacts were calculated.

This assessment is presented in the first column of results in Table 4 and indicates that more than 90% of the calculated environmental impacts of the building structure and thermal envelope are captured at concept design in comparison with detailed design. Thus, the lack of detail available at concept design does not appear to significantly affect calculated environmental impacts.

Table 4. Assessment of environmental impacts by design stage.

Indicator	Concept as a % of detailed	Concept as a % of constructed
Global warming	94	50
Stratospheric ozone depletion	103	56
Acidification of water and soil	94	51
Eutrophication	93	43
Photochemical oxidant formation	91	44
Depletion of abiotic resources (elements)	93	43
Depletion of abiotic resources (fossil fuels)	94	51
Primary energy (total)	98	53

[4] Further information about the building performance sketch is provided in Appendix B.

Differences arise because assumptions about materials at concept design are replaced with better data later in the design process. For example, reinforcement content in concrete at concept design will be refined by detailed design. Similarly, compressive strengths of concrete required for different parts of the building will be known by detailed design.

It is also of interest to get a sense of the scale of environmental impacts that are locked in at early design in comparison with the constructed building. For this assessment, the environmental impacts calculated at concept design are compared to environmental impacts calculated based on a schedule of quantities (SoQ) provided by the building contractor for all building elements. The results of this assessment are shown in the second column of results in Table 4.

This analysis indicates that embodied environmental impacts calculated for the structure and enclosure at concept design already comprise 43–56% of the overall embodied environmental impacts of all elements of the constructed building.

5.3 Method for reference buildings development

In order to develop reference buildings suitable for early design application, the following steps were carried out:

1. Development of a methodology for modelling accurate enough material quantities in reference buildings for early-stage design (see section 5.3.1).
2. Application of a methodology for modelling accurate enough operational energy in reference buildings for early-stage design (see section 5.3.2).
3. Development of data to support calculation of life cycle impacts (see section 0).
4. Development of a resource (*LCAQuick – Office*) that brings together the outputs from steps 1 to 3 above to calculate life cycle environmental impacts of buildings at early design (see section 5.3.4). *LCAQuick – Office* is available for download from the BRANZ website at www.branz.nz/buildingLCA.

5.3.1 Methodology for obtaining accurate enough material quantities

In order to complete this section of work, the following stages were completed:

- Stage 1: Development of a quality assurance process against which material quantities obtained from BIM models could be tested (see section 5.3.1.1).
- Stage 2: Application of a methodology for calculating building material quantities (see section 5.3.1.2).
- Stage 3: Quality assurance check of the simulation methodology for building materials (see section 5.3.1.3).

5.3.1.1 Stage 1: Development of a quality assurance process

When developing building simulations for the purposes of inputting to building LCA, the reliability of the underlying models should be determined. These quality assurance methods used in other areas of building simulation are applicable to building LCA:

- Minimisation of uncertainty in the different areas of building simulation where possible prior to their integration in the building LCA. This is in the calculation processes for building material quantities and operational energy and water use,

and the environmental impacts attributed to materials and processes, which are used for the calculation of indicators.
- Comparison of building LCA results with a truth model to determine if the simulation meets established maximum calibration tolerances. This is the best method for developing a quality assured simulation method.
- Comparison of materials and building LCA results to published results from other studies.

Table 5 provides a summary of the quality assurance methods used in the development of the building LCA reference buildings.

Table 5. Quality assurance methods used in development of reference office buildings.

Building LCA data requirement	Simulation area	Output	Quality assurance process used in this research
Material and process environmental impacts (all modules)	LCA modelling	Material and process environmental coefficients for building materials, grid electricity, water and waste	Third-party review by LCA expert and comparison with published data (Appendix D)
Material quantities (modules A1–A3, B2, B4, C1–C4, D)	Calculating material quantities using BIM	Volume, mass and area quantities of individual materials and construction systems	Development and use of a quality simulation process through calibration
Operational energy (module B6)	Operational energy simulation	Annual energy (electricity and gas) consumption	Use of a quality assured simulation methodology (through calibration), limiting data assumption uncertainties by using assumptions formulated from real building data and comparison to existing benchmarks
Operational water (module B7)	Operational water simulation	Annual water consumption	Apply existing operational water use benchmarks based on real building use developed by Bint (2012)

At this time, there is no calibration methodology for BIM models developed for the purpose of calculating building material quantities for building LCA during early design. The following sections detail how a calibration method was developed. In particular, this included definition of what is the true value and the maximum acceptable calibration tolerance (see Appendix C).

Defining the true value

The true value of a phenomenon is defined by what can be physically and practically measured by current best-practice methods and tools. For each calculated environmental impact for a building using LCA, the true value is the sum of:

- the appropriate impact coefficient for each material for each relevant stage of the life cycle multiplied by the quantity of the material used in a building

- the appropriate impact coefficient for each energy carrier to a building multiplied by the quantity of that form of energy used in a building
- the appropriate impact coefficient for water use in the building.

Ideally, quantities of materials used and energy and water used are obtained from measurement once the building is occupied in order to derive a true value. However, during early design, physical measurement is impossible as the building is not yet constructed and occupied. For materials, an SoQ from a quantity surveyor provides the next best alternative as an accepted best-practice method for defining the true value.

Defining how close is close enough to reality

ASHRAE Guideline 12:2002 (ASHRAE, 2002) provides maximum acceptable calibration tolerances for energy simulation models. These are expressed in terms of a mean bias error (MBE) and a coefficient of variation of root mean squared error (CV(RMSE)), which are covered further in Appendix C. An acceptable tolerance is not available for other modelling applications. The ASHRAE maximum acceptable calibration tolerance values could be adopted but no guidance for defining values is given.

However, other calibration standards do provide some guidance. The Measurement & Verification (M&V) Guideline 3.0 (US DOE, 2008) states that, whenever project-specific calibration tolerances are required, that "specific calibration goals should be set for each project based on the appropriate level of effort".

Reasonable accuracy requirements can be defined as those that are not overly strict or too lenient compared to modelling time constraints, decision making and performance goals. In the context of this research, the terms 'reasonable' and 'appropriate' for building LCA calibration are defined by how the results are calculated and how the results are to be used.

The LCA building performance sketch (BPS) produces results for iterative testing of design decisions in the early phases of the design process. This simulation must be conducted quickly and easily to produce simulation results that are accurate enough to allow building designers to make informed design decisions (Donn , Selkowitz & Bordass, 2012). Therefore, defined values for building LCA maximum acceptable calibration tolerances must integrate into this process so they help conduct a BPS rather than inhibit it.

Building cost planning provides the best precedence for defining maximum acceptable margins of error allowable throughout the different phases of the design process applied to the calculation of building material quantities.

Table 6 shows that, for concept design, ±10–20% compared to the truth model is accepted. As the reference BPS is focused solely on structure and thermal envelope (rather than the whole building), this ±10–20% must be apportioned to match the scope of the BPS.

Table 6. Summary of acceptable cost planning margins of error by stage of design.

Design phase	Maximum acceptable accuracy margin of error
Concept design	±10–20% (Holm et al. (2005) cited in Samphaongoen (2010))
Developed design	±5–10% (Holm et al. (2005) cited in Samphaongoen (2010))
Detailed design	±2–4% (Holm et al. (2005) cited in Samphaongoen (2010))
General	±5–10% (Smith & Jaggar, 2006)

This was calculated by apportioning the minimum level of accuracy (±20%) for the whole building's margin of error to those elements included in the BPS (which comprise 50.9% of the developed design cost estimate according to a schedule of quantities provided for one of the reference buildings). Table 7 summarises this proportional attribution applied to each building element. The result is that the maximum calibration tolerance for the BPS is ±10.9%. The percentage margin of error figures listed in Table 7 are the maximum calibration tolerances by building element the BPS must meet.

Table 7. Maximum acceptable margin of error by building element.

NZIQS elements		Developed design elements cost as a % of the total developed design cost	Maximum acceptable margin of error by element
E2	Substructure	6.7%	±1.3%
E3	Frame	8.2%	±1.6%
E4 + E7	Structural walls + exterior walls and exterior finish	10.0%	±2.0%
E5	Upper floors	7.0%	±1.4%
E6	Roof	4.4%	±0.9%
E8	Windows and exterior doors	18.3%	±3.7%
Apportioned total of ±20.0% MBE		50.9%	±10.9 %

5.3.1.2 Stage 2: Application of a methodology for calculating building material quantities

Building material quantities are required to calculate the environmental impacts associated with modules A1–A3, A4, A5, B2, B4, C1–C4 (and D). The methodology utilised in this research to calculate quantities for the BPS of reference office buildings is based on Berg's research (2014). Berg (2014) developed a quality assured methodology for how to use BIM to calculate accurate building material quantities for early design phase embodied energy assessment. Critically, he defined how detailed a BIM model should be, both in terms of the detail required of the BIM geometry (an illustration of which is provided in Figure 10) and the individual BIM objects (Table 8).

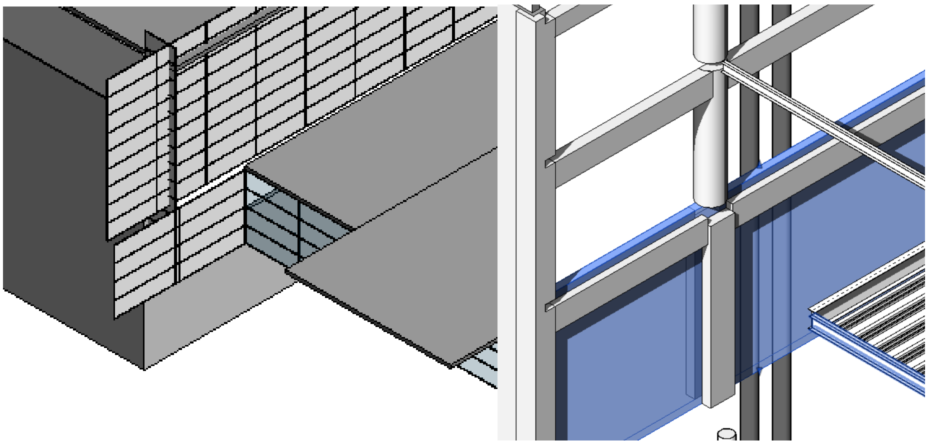


Figure 10. Example of BIM geometry required to obtain accurate material quantities.

Table 8. Level of development needed to obtain accurate results.

BIM object	3D modelled detail level of development (LOD)	
Foundation strip footing	A1010.30 – Column Foundations (Deep Foundations)	LOD 200
Concrete pile	A1010 – Standard Foundations	LOD 200
Circular hollow section (CHS) column with foundation footing	B1010.10 – Floor Structural Frame (Steel Framing Columns)	LOD 300
Concrete foundation slab	A4010 – Standard Slabs-on-Grade	LOD 200
Hollow-core precast floor slab	B1010.20 – Floor Decks, Slabs, and Toppings (Composite Floor Deck)	LOD 200
In situ concrete floor		
Precast solid concrete floor slab		
CHS column	B1010.10 – Floor Structural Frame (Steel Framing Columns)	LOD 300
Steel universal beam (UB)	B1010.10 – Floor Structural Frame (Steel Framing Beams)	LOD 300
In situ concrete wall	B2010 – Exterior Walls	LOD 300
Concrete masonry brick wall		
Precast concrete wall		
Timber-framed wall		
Double-skin façade	B2020.30 – Exterior Window Wall	LOD 350
Roof	B1020.10 – Roof Structural Frame	LOD 200

YouTube video tutorials are available on the BRANZ media channel that provide further information on how to construct an accurate enough BIM model for undertaking a building LCA. (See the LCA playlist at www.youtube.com/user/BRANZmedia/playlists.)

5.3.1.3 Stage 3: Quality assurance check of the simulation methodology for building material quantities

Having developed a quality assurance process and minimum requirements for LOD and BIM geometry based on Berg (2014), the quality assurance process was tested on a reference building to check if it would calculate sufficiently accurate building material quantities for the purposes of building LCA. Table 9 shows the results from the pre-calibration BIM model compared to the true value taken from the developed design SoQ. Overall, the MBE passes as it is within the ±10.9% maximum calibration tolerance defined in section 5.3.1.1. However, at an individual element level, there are errors in the upper floors and roof elements (Table 9) outside of the individual elemental tolerances shown in Table 7.

Further inspection of the BIM model showed these errors were caused by:

- upper floors – discrepancies in the SoQ documentation and the building consent documentation
- roof area – missing plant roof and steel roof overhang missing (human modelling error).

Table 10 and Figure 11 show the result of the quality assurance test following corrections to the BIM model. The post-calibration BIM model results pass all maximum calibration tolerance requirements, demonstrating that the methodology is quality assured to produce sufficiently accurate results for future buildings.

Table 9. Pre-calibration quality assurance results for one tested reference building

NZIQS elements		BPS maximum calibration tolerance (from Table 7)	True value – SoQ (simplified for sketch design) [GJ/m²]	BPS [GJ/m²]	MBE BPS to true value	Calibration pass or fail
E2	Substructure	±1.3%	0.651	0.648	-0.08%	PASS
E3	Frame	±1.6%	0.319	0.273	-1.35%	PASS
E4 & E7	Structural walls and exterior walls and exterior finish	±2.0%	0.354	0.322	-1.00%	PASS
E5	Upper floors	±1.4%	0.477	0.375	-3.01%	FAIL
E6	Roof	±0.9%	0.608	0.579	-0.85%	FAIL
E8	Windows and exterior doors	±3.7%	0.994	1.000	0.18%	PASS
Total		±10.9%	3.403	3.199		PASS
MBE Total						-6.42%
CV(RMSE) Total						14.55%

Table 10. Post-calibration quality assurance results for one tested reference building.

NZIQS elements		BPS maximum calibration tolerance (from Table 7)	True value – SoQ (simplified for sketch design) [GJ/m²]	BPS [GJ/m²]	MBE BPS to true value	Calibration pass or fail
E2	Substructure	±1.3%	0.651	0.648	-0.08%	PASS
E3	Frame	±1.6%	0.319	0.279	-1.19%	PASS
E4 & E7	Structural walls and exterior walls and exterior finish	±2.0%	0.354	0.372	0.52%	PASS
E5	Upper floors	±1.4%	0.477	0.480	0.09%	PASS
E6	Roof	±0.9%	0.608	0.633	0.71%	PASS
E8	Windows and exterior doors	±3.7%	0.994	1.000	0.19%	PASS
Total		±10.9%	3.403	3.412		PASS
MBE Total					0.24%	PASS
CV(RMSE) Total					0.55%	PASS

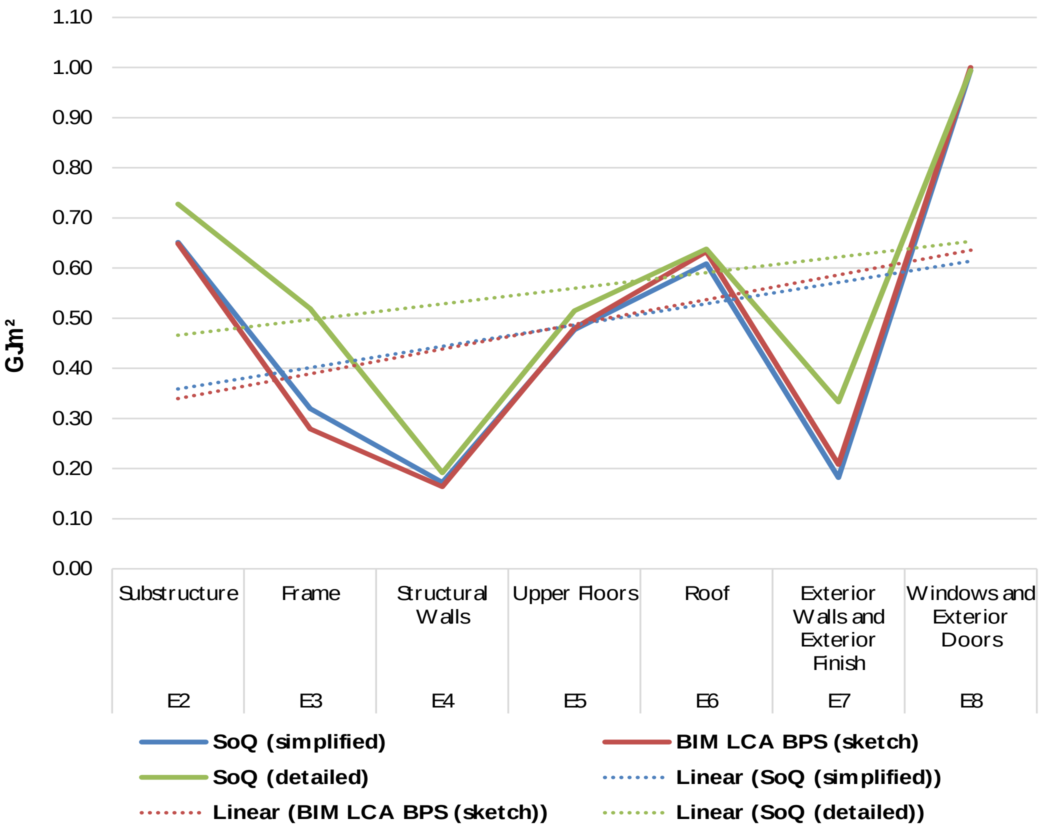


Figure 11. Example of post-calibration quality assurance results for one tested reference building.

5.3.2 Methodology for obtaining accurate enough operational energy

Building energy consumption data is required to calculate the environmental impacts associated with module B6 operational energy as defined in the standard EN 15978 (CEN, 2011) and outlined in BRANZ Study Report SR349 (Dowdell & Berg, 2016). Table 11 shows the energy end uses required for building LCA in EN 15978 and whether they are included or excluded from the scope of the BPS reference building models. Energy uses listed f–i in Table 11 are not specifically itemised in the BEES template energy models used in this work (see Section 5.3.2.1) and is not a level of detail typically available at early design so are excluded.

Table 11. Scope of energy end uses included in the reference buildings.

EN 15978 (CEN, 2011) requirement	BPS modelling
Building-related/building-integrated technical systems consuming operational energy a. Heating b. Air conditioning (cooling and humidification/dehumidification) c. Ventilation d. Lighting e. Auxiliary energy used for pumps, control and automation	Included
Building-related/building-integrated technical systems consuming operational energy f. Lifts g. Escalators h. Safety and security installations i. Communication systems Any building-integrated technical systems consuming operational energy that are necessary for the technical and functional performance of the building must be included in B6 operational energy and reported and communicated separately.	Excluded BEES states contributes ~10%
Non-building-related energy j. Any plug-in appliances, e.g. plug loads Energy use of appliances that are not building related but included in the operational energy simulation must be reported and communicated separately.	Included BEES states contributes ~30%

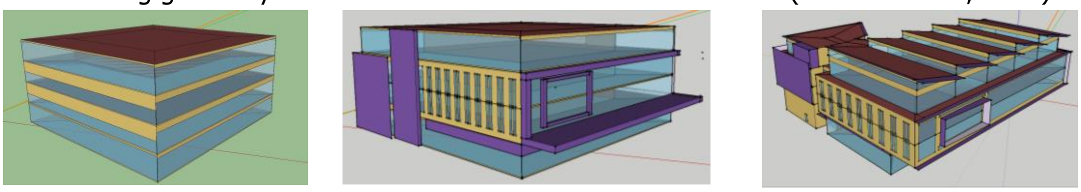
In order to develop accurate enough building energy models for the purposes of calculating life cycle environmental impacts based on early design information, the following stages were carried out:

- Stage 1: Application of an energy modelling methodology derived from BEES.
- Stage 2: Quality assurance check of the building energy simulation.

5.3.2.1 Stage 1: Application of the BEES energy modelling methodology

Some energy end-use categories required by EN 15978 (CEN, 2011) are beyond what may be typically considered within the scope of early design when simplified/template modelling geometry rather than a building's true form is modelled (illustrated in Figure 12).

Simple or template modelling geometry	Medium modelling geometry	Detailed modelling geometry (Donn & Garde, 2014)



Pre-design scenario testing	Concept design phase	Developed/detailed design phase

Figure 12. Illustration of energy model detail with design phase.

BPS models developed for the reference office buildings are intended to provide an operational energy input to the calculation of a building's environmental impact across its life cycle. To achieve this aim, the scope of the energy simulation models needs to be more detailed than would typically be considered at concept design. **Error! Not a valid bookmark self-reference.** details the main differences between energy models required for building LCA and those typical of concept design. The main differences are in the areas of HVAC system design and layout, the building geometry and thermal zoning.

Table 12. Design phase level of detail required and BPS modelling method used for the reference buildings.

Building energy simulation object	Design phase	BPS modelling methodology
Windows	Concept	Whole window R-value (glazing and frame) calculated based on WEERS standard window design
Construction thermal bridging	Concept	Excluded
Geometry/zoning rules	Geometry = detailed Zoning = concept More detailed zoning was not possible due to a lack of information about the layout of the HVAC systems.	Detailed building form with simplified zoning rules applied to internal spaces
Airflow between zones	Concept	Excluded
HVAC system selection and design	Preliminary HVAC system is template level detail (representative of typical New Zealand commercial office buildings), not specific to the actual systems used in the buildings as this information was not available.	Buildings are modelled with all internal zone volumes serviced by the four most common HVAC systems in New Zealand commercial office buildings – variable air volume (VAV with a gas boiler), electric VAV, heat pumps and fan coil units. The final energy consumption is an average of all four systems.
Natural ventilation	Excluded – all ventilation modelled as mechanical.	

Note: Specific energy/thermal modelling information such as schedules, HVAC and so on to assist with building energy modelling are provided in the module B6 operational energy datasheet available from www.branz.nz/buildingLCA. See BRANZ Study Report SR351 (Dowdell et al., 2016) for more information.

Quality assurance checking of energy simulation models is normally undertaken by comparing simulated energy demand with actual energy demand post-occupancy (the true value). If the simulation results do not accurately (within acceptable tolerances) represent reality, the results are less meaningful. This gap between simulation and reality is called the performance gap, and it has been shown that actual energy consumption will usually be twice what is actually predicted through simulation (Menezes et al., 2011).

In order to reduce the size of the performance gap as far as possible, the reference buildings were modelled based on BEES (Amitrano et al., 2014a, 2014b) using BEES template energy models produced as an output of simulation methodology research (Gates, 2013; Cory, Gates & Donn, 2011) because:

- it represents a simulation methodology that has been quality assured through calibration
- simulation assumptions are based on data of real buildings in operation.

The templates[5] provide a set of standardised energy simulation modelling defaults based on monitored data of New Zealand commercial buildings (in operation) recorded as part of the BEES research project. Work undertaken by Cory, Gates and Donn (2011) showed that building energy models constructed using these templates with simple level geometry (Figure 12) and following internal zoning rules could produce annual energy consumption results with a 15% difference and an 11% variance range when compared to real energy data. This variability is accepted for this research.

The authors concluded that the largest source of inaccuracy was caused by the simplified thermal zoning as a result of using template geometry. Recognising this, the BPS energy models developed for this work are modelled to detailed geometry levels. However, detailed zoning was not possible due to a lack of information about the layout of the HVAC systems.

5.3.2.2 Stage 2: Quality assurance check of the building energy simulation methodology

The methodology developed by Cory, Gates and Donn (2011) was applied to a reference building for which post-occupancy energy consumption data were available to test if the reported accuracy was possible. Table 13 shows the results of three different levels of building simulation modelling detail. All three of these methods were compared to actual energy consumption in the building. Of the three, the BPS methodology simulates energy consumption closest to the building's actual use, with a difference of -8.3%. This is within the acceptable simulation tolerance reported by Cory, Gates and Donn (2011).

Table 13. Quality assurance results of energy simulation for a tested reference building.

Simple/template modelling geometry	Detailed modelling geometry	BPS methodology: detailed geometry with simplified internal thermal zoning
-12.6% compared to actual energy consumption on a kWh/m² GFA basis. New Zealand generic modelling assumptions for loads and construction systems used.	-21.7% compared to actual energy consumption on a kWh/m² GFA basis. Under simulated compared to actual performance as based on design level project-specific loads and detailed HVAC that were not New Zealand specific.	-8.3% compared to actual energy consumption on a kWh/m² GFA basis. New Zealand generic modelling assumptions for loads and schedules of operation and detailed geometry and as-documented constructions.

5.3.3 Method for obtaining data to support calculation of environmental impacts

At commencement of this research project, little LCA-based New Zealand data for construction materials and processes was available, an exception being Nebel, Alcorn

[5] Available for use at www.branz.co.nz/cms_display.php?sn=169&st=1&pg=9697.

and Wittstock (2011). Other published studies consist of embodied energy and greenhouse gas emissions data for selected materials (for example, Alcorn (2010) and Love (2010)). Most published data only considers the manufacturing phase of materials, covering modules A1–A3 as set out in BRANZ Study Report SR349 (Dowdell & Berg, 2016).

For this project, LCA-based indicators needed to be calculated for the following:

- Materials commonly considered during early design. This was restricted to materials that may be used in a building's structure and thermal envelope only. This needed to include manufacture of the materials (modules A1–A3) but also other life cycle stages including transport and installation (modules A4 and A5), maintenance (module B2), replacement (module B4), end of life (modules C1–C4) and, additionally, potential benefits and loads beyond the building system boundary (module D).
- Generation of New Zealand grid electricity, as the main supplier of energy to commercial buildings, and combustion of natural gas to provide heat (for use in module B6).
- Production of tap water to commercial buildings and treatment of wastewater from commercial buildings (for use in module B7).

On completion, the data needed to undergo an independent review to check for adequacy for decision making at early design.

5.3.3.1 Development of materials-related environmental impact data

A list of materials was compiled that was based on materials used in the structures and thermal envelopes of the 10 reference buildings. Some further materials were added to this list to provide potential alternatives to materials used in these buildings. An example is concrete with different proportions of pulverised fuel ash (PFA) or ground granulated blast furnace slag (GGBS) instead of cement. A listing of modelled materials is provided in Appendix D.

For each material, data on environmental impacts[6] of manufacture was collected according to the following hierarchy of sources, where those higher in the list were considered more desirable from a data quality perspective than sources lower down the list:

- Independently verified EN 15804 (CEN, 2013) compliant EPDs for New Zealand manufactured or imported products (for example, EPDs of construction products registered on the Australasian EPD® Programme[7]) or published critically reviewed life cycle inventories (LCIs) developed in accordance with and reviewed for compliance with EN 15804 (CEN, 2013) and relevant PCR (if available).
- Independently verified EPDs or published critically reviewed LCIs developed to LCA standards other than EN 15804 (CEN, 2013) for New Zealand manufactured or imported products.
- Independently verified EN 15804 (CEN, 2013) compliant EPDs for the same or similar products manufactured in other geographical locations (for example, EPDs

[6] Based on EN 15978 (CEN, 2011) and list 1 indicators listed in BRANZ Study Report SR293 (Dowdell, 2014) plus total primary energy.
[7] www.epd-australasia.com

registered on the International EPD® System[8] or IBU[9]) or published critically reviewed LCIs developed in accordance with and reviewed for compliance with EN 15804 (CEN, 2013) and relevant PCR (if available).
- Independently verified EPDs or published critically reviewed LCIs developed to standards other than EN 15804 (CEN, 2013) for the same or similar products manufactured in other geographical locations.
- Modelled processes based on generic data, adapted where possible for location of manufacture (for example, including use of New Zealand grid electricity for processes in New Zealand).
- Modelled processes based on generic data in an unadapted form.

Modelling of processes was carried out in the GaBi proprietary LCA software provided by thinkstep[10] using the EcoInvent database (version 3.1)[11] developed by the EcoInvent Centre. The EcoInvent database was selected because it is comprehensive and is provided at the unit process level, enabling data to be adapted to more closely reflect New Zealand conditions where possible.

Environmental impacts arising from life cycle stages beyond manufacture were mainly modelled, although some data was available in EPDs, which was used or incorporated into modelling. Modelling of stages beyond modules A1–A3 was informed by defaults provided in datasheets developed by BRANZ. BRANZ Study Report SR351 (Dowdell et al., 2016) provides background information on their development. The datasheets have been developed for use at early design of office buildings and may be useful for other applications. They are available at www.branz.co.nz/buildingLCA.

Materials-relevant datasheets that provided the underlying data for modelling of stages beyond manufacture include the following:

- Weighted-average transport distances of construction products from the last manufacturer, fabricator or assembler to construction sites in Auckland, Wellington and Christchurch (contributing to module A4 in EN 15978 (CEN, 2011)).
- Waste generated at construction sites (percentage by mass), percentages of waste going to reuse, recycling, energy recovery and landfill/cleanfill, plus information on likely recycling route (contributing to module A5 in EN 15978 (CEN, 2011)).
- Service life of an office building in the absence of building-specific information (for the use stage covered by modules B1–B7 in EN 15978 (CEN, 2011)).
- Typical maintenance of building products during the building service life (contributing to module B2 in EN 15978 (CEN, 2011)).
- Typical replacement of building products during the building service life (contributing to module B4 in EN 15978 (CEN, 2011)).
- Typical and best-practice waste diversion rates (by mass) from landfill/cleanfill following building end of life. Reuse, recycling and recovery rates are provided as well as information on recycling or recovery route. This contributes to module C1 in EN 15978 (CEN, 2011)).

A matrix of materials by life cycle stage by environmental indicator was developed for each of Auckland, Wellington and Christchurch. These matrices provide the basis for the calculation of materials-related environmental impacts in *LCAQuick – Office*.

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[8] www.environdec.com
[9] http://ibu-epd.com/en/epd-program/published-epds/
[10] www.thinkstep.com/software/gabi-lca/gabi-professional
[11] www.ecoinvent.org

Information about the scope of data collected, assumptions and sources is provided in Appendix D.

5.3.3.2 Stage 2: Development of energy-related environmental impact data (for module B6)

Given the amount of grid electricity that is used in office buildings, it is important that data is available that facilitates the calculation of associated environmental impacts. Furthermore, use of a common dataset for grid electricity aids consistency across different building LCA studies.

Research carried out at the New Zealand Life Cycle Management Centre at Massey University, with input from BRANZ and EnviroMark, led to the development of a New Zealand grid electricity model on a 'per kWh low-voltage electricity at the plug' basis. The model was developed in the GaBi LCA software using EcoInvent 3.1 as a supporting database. The results of this work are published (Sacayon Madrigal, 2016).

Using the LCA model developed by Sacayon Madrigal (2016), which used data for a single year, BRANZ expanded the model so that it could calculate environmental impacts based on a 3-year average. This was developed based on findings by Sacayon Madrigal (2016) and aims to smooth out peaks and troughs in grid environmental impacts, which are a result of the amount and location of rainfall in each year and impacts on the amount of electricity generated using hydroelectricity. Data for the supply of electricity came from MBIE (2013, 2014, 2015).

The data is provided:

- in Excel as a list of indicators and as an LCI
- as a .gbx file for users of the GaBi software
- in other formats available from GaBi (for example, EcoSpold).

All versions can be downloaded from www.branz.co.nz/buildingLCA. Information is also provided in BRANZ Study Report SR351 (Dowdell et al., 2016).

Data covering natural gas supply and combustion to provide heat is based on EcoInvent data, adapted for extraction and transmission in the work of Sacayon Madrigal (2016).

Further information is available in Appendix D.

5.3.3.3 Development of water-related environmental impact data (for module B7)

Data for the supply of tap water to office buildings and treatment of wastewater from office buildings was modelled using generic data from EcoInvent. Further information is provided in Appendix D.

5.3.3.4 Stage 4: Review of data

Data was compared to other published sources of data. In practice, data was mainly available for modules A1–A3. Comparisons with published data are provided in Appendix D.

In addition, Tim Grant, Director of lifecycles[12] based in Australia, reviewed the data developed for the project. The review was carried out in January and February 2016. The scope of the review was to check the data for appropriateness for decision making during early-stage design.

As a result of the review, a number of recommendations were made to improve the data, all of which were implemented. The data was then re-reviewed to check that recommended amendments were made to the reviewer's satisfaction.

5.3.4 Development of a resource to calculate building life cycle environmental impacts (*LCAQuick – Office*)

An Excel-based tool was developed that could take outputs of materials and energy simulations and combine these with environmental impact data to calculate building environmental impacts. The tool was used to generate results for the reference buildings set out in section 6.

Reference building results were subsequently added to the tool to provide a basis for comparison with buildings that are undergoing concept and preliminary design.

The tool was further developed with a more user-friendly interface and became *LCAQuick – Office*. This was beta tested in 2015 and refined and updated to form the final versions available at www.branz.co.nz/buildingLCA.

An introduction to *LCAQuick – Office* is provided in BRANZ Study Report SR349 (Dowdell & Berg, 2016). The resource is accompanied by YouTube training videos (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists), which provide guidance on modelling in BIM to obtain accurate material quantities and how to use *LCAQuick – Office*.

5.3.4.1 Quality assurance of building LCA performance sketch results

Subsequent to quality assuring the calculation of building material quantities, energy consumption and environmental impact data, the final quality assurance process was to check the calculated environmental impact results for the reference office buildings at a whole-building level. For this, calculated building level environmental impacts were compared to published case studies and/or benchmarks. The purpose of this comparison was to ascertain if the results looked reasonable.

This check was conducted for the following, based on data found for comparison:

- Modules A1–A3 total primary energy.
- Module B6 energy consumption.
- Whole life cycle (including module D) for potential climate change impact.

Figure 13 shows module A1–A3 total primary energy results of the reference office buildings modelled in Auckland (Zone 1 or Z1).

The average across all 10 buildings was 3.1 GJ/m² GFA/year, which compares well with the 3.4 GJ/m² GFA/year from Berg (2014) and 3.6 GJ/m² GFA/year from Fernandez (2008).

[12] www.lifecycles.com.au/

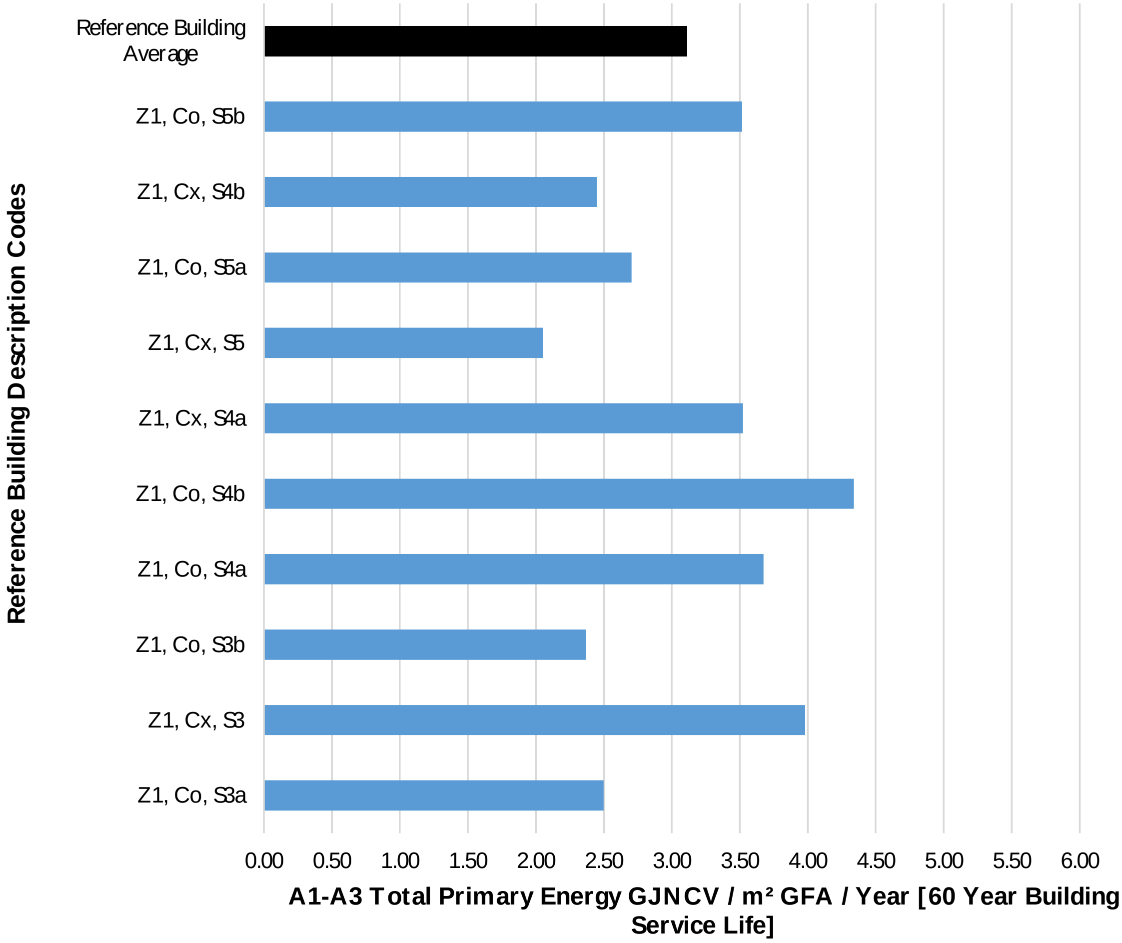


Figure 13. Comparison of module A1–A3 total primary energy.

Figure 14 shows the simulated energy consumption results for the 10 reference office buildings for module B6 using the Auckland climate file. They range from 78 to 152 kWh/m² GFA/year, with a calculated average of 102 kWh/m² GFA/year.

While at the lower end, it is within an acceptable range compared to the BEES prototypical average of ~100–128 kWh/m² GFA/year (Cory & Amitrano, 2014).

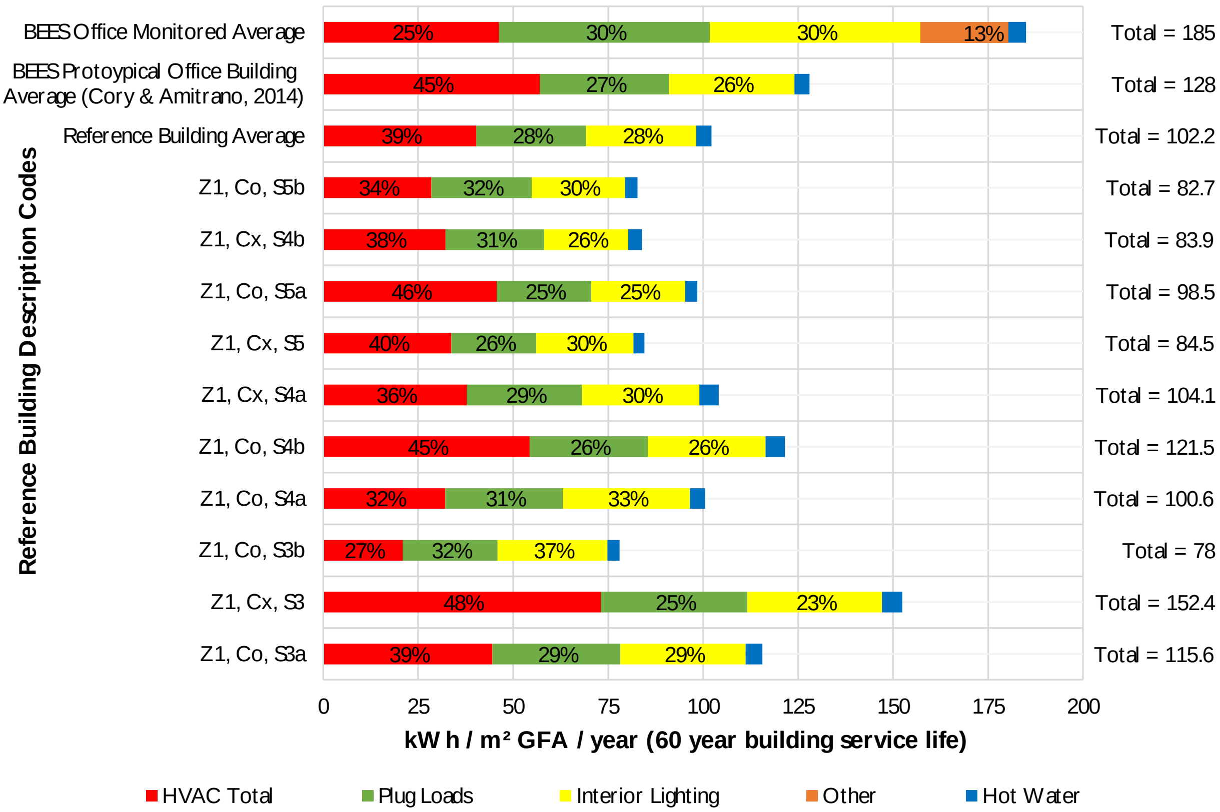


Figure 14. Comparison of module B6 operational energy.

Figure 15 shows the potential climate change impact results of the 10 reference office buildings over a 60-year building service life. Three published case study buildings are also presented (in yellow) from Athena Sustainable Materials Institute (2013, 2014, 2015). Where these buildings use a different building life, the results were pro-rated.

Detailed comparison to these case studies is impractical due to differences in datasets, scope and building design. However, it does illustrate that the reference buildings results look reasonable.

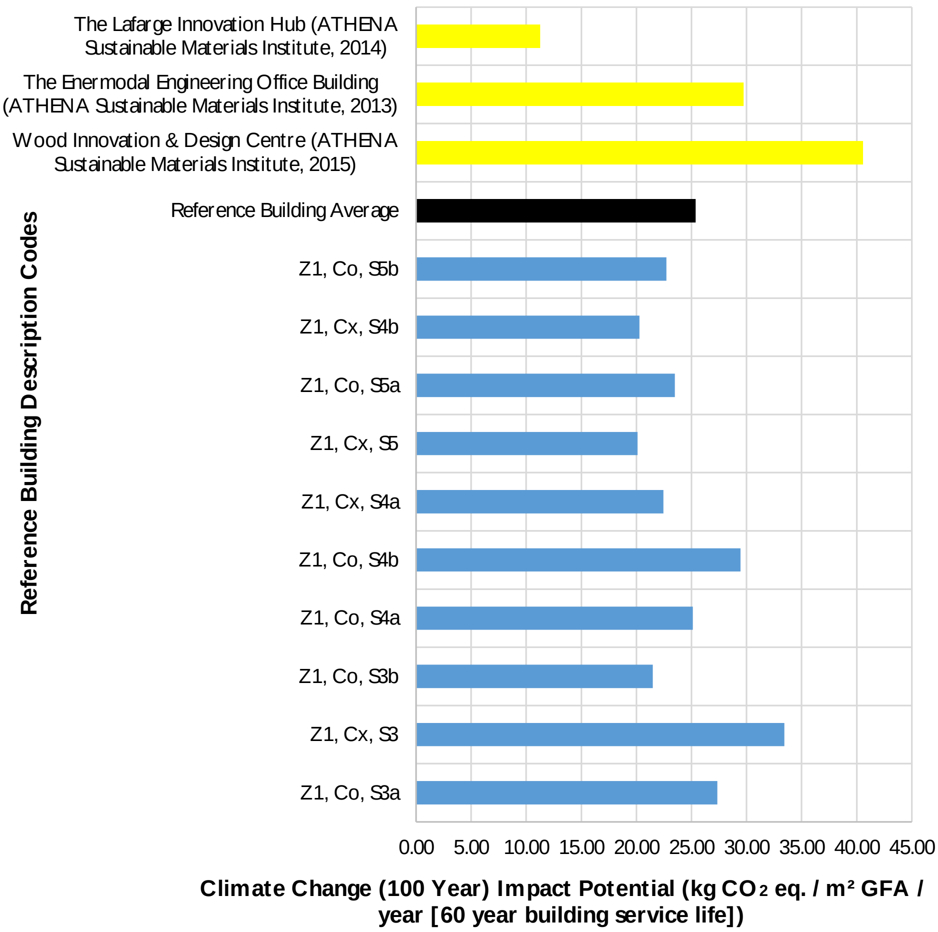


Figure 15. Comparison of life cycle potential climate change impact results.

6. Reference office building indicator results and observations

Indicators presented in this section represent potential environmental impacts based on midpoint characterisation. Further information on this is provided in the BRANZ Study Report SR293 (Dowdell, 2014).

This section presents the calculated indicators of the reference office buildings:

- Total potential impacts over a 60-year building service life
- Comparison of results expressed as GFA and NLA
- Results by climate zone
- Results by size class
- Results by structural system.

Table 14 shows how indicator results are grouped according to the scale and primary area of protection.

Table 14. Grouping of indicator results by scale and area of protection.

Scale	Primary area of protection[13]	Indicator
Global	Ecosystem	Climate change (100 year)
	Ecosystem	Stratospheric ozone depletion
Regional	Ecosystem	Acidification (land and water)
	Ecosystem	Eutrophication
	Health and wellbeing, ecosystem	Tropospheric ozone formation
Global[14]	Natural resources	Abiotic depletion (elements)
	Natural resources	Abiotic depletion (fossil fuels)
	Natural resources	Total primary energy

The identity of the reference office buildings is not provided. Therefore, a coding system has been devised that provides information about the buildings without revealing their identities. The coding structure consists of four parts as follows:

- The building's H1 zone definition – zones 1, 2, or 3 (Z1, Z2, or Z3) corresponding to Auckland, Wellington or Christchurch respectively. This is not the building's original location. Instead, it is the location the building has been modelled in for the energy simulation. All 10 buildings have been modelled in the three locations.
- The building's primary activity – commercial office (Co) or commercial mixed (Cx).
- Building size – size class 3 or S3 (1,500–3,499 m^2 GFA), size class 4 or S4 (5,300–8,999 m^2 GFA) and size class 5 or S5 (9,000 m^2 GFA and more).
- A lower case letter (a or b) that differentiates when there is more than one building in the same location, with the same activity and size class.

A summary of information about each of the reference office buildings is provided in Table 15.

[13] From BRANZ Study Report SR293 (Dowdell, 2014).
[14] Calculated using global characterisation factors although this may also be considered as a regional issue.

Table 15. Summary of reference office buildings.

Building identification code	Gross floor area (GFA)	Net lettable area (NLA)	Original location and zone	Building activity	Size class	Structural system (type)	Structural system (material)
Zx, Co, S3a	2,021	1,684	Auckland, Z1	Commercial office (83%)	3	Braced frame and shear-walled frame systems	Composite: concrete/steel
Zx, Cx, S3	1,933	1,642	Christchurch, Z3	Commercial mixed (office 57%, retail 28%)	3	Post-tensioned LVL frames and walls	Timber
Zx, Co, S3b	1,814	848	Auckland, Z1	Commercial office (47%) (car parking 39%)	3	Rigid frame system	Steel
Zx, Co, S4a	7,789	5,088	Auckland, Z1	Commercial office (65%) (car parking 24%)	4	Rigid frame system	Composite: concrete/steel
Zx, Co, S4b	5,911	4,430	Wellington, Z2	Commercial office (75%)	4	Rigid frame system	Composite: concrete/steel
Zx, Cx, S4a	6,373	5,446	Christchurch, Z3	Commercial mixed (office 86%)	4	Post-tensioned LVL frames and walls	Timber
Zx, Cx, S4b	6,625	4,256	Auckland, Z1	Commercial mixed (office 51%, retail 13%)	4	Braced frame and shear-walled frame systems	Reinforced concrete
Zx, Cx, S5	22,912	13,731	Auckland, Z1	Commercial mixed (office 59%, car parking 31%)	5	Rigid frame system	Reinforced concrete
Zx, Co, S5a	10,864	9,180	Wellington, Z2	Commercial office (office 74%, car parking 3%)	5	Rigid frame system	Reinforced concrete
Zx, Co, S5b	13,247	10,592	Auckland, Z1	Commercial office (80%)	5	Braced frame and shear-walled frame systems	Reinforced concrete

6.1 Indicators over a 60-year service life

Energy simulations for module B6 operational energy have been carried out for the 10 buildings for each of zones 1, 2 and 3 providing a total of 30 results.

Total operational energy (including plug loads) calculated for the office buildings over 60 years is summarised in Figure 16 and shows that:

- energy use increases with size class, due to the greater numbers of people in larger buildings
- energy use in Auckland is consistently the lowest, with Wellington averaging 16% higher and Christchurch 19% higher for the modelled buildings due to greater heating and/or cooling needs.

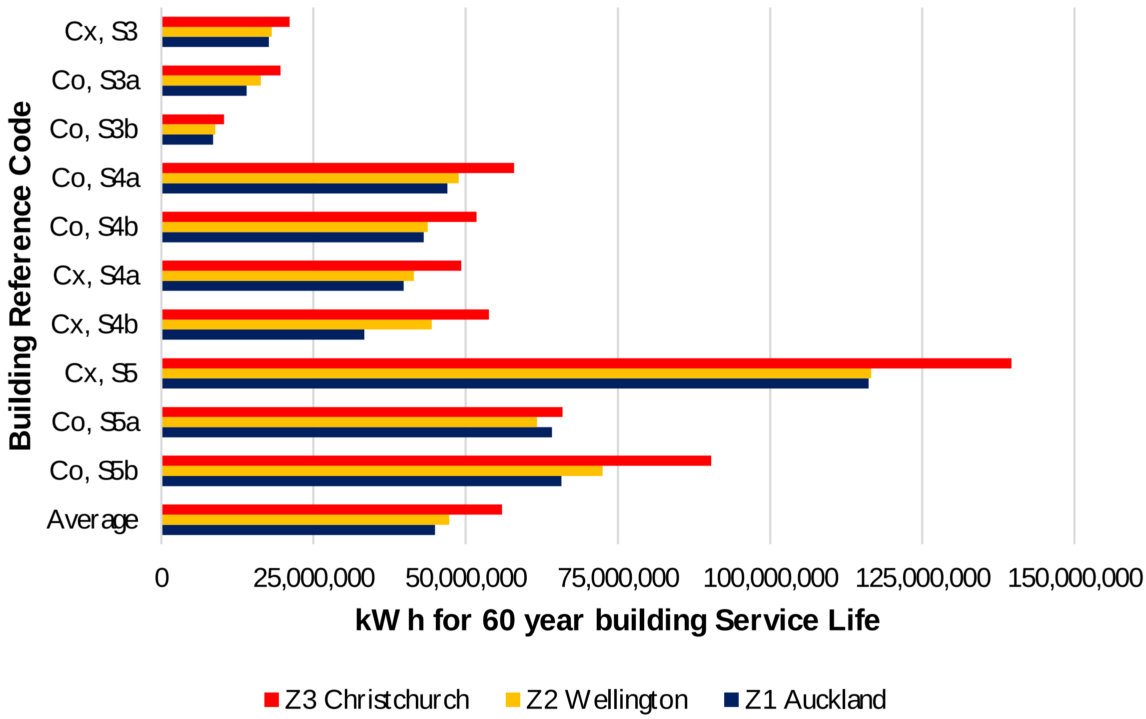


Figure 16. Total modelled operational energy (including plug loads) for the reference office buildings over a 60-year service life.

Figure 17 to Figure 24 provide indicator results across the 60-year service life of the modelled reference office buildings. These results are divided by area of protection (from study report SR293 [Dowdell, 2014]) and scale, being ecosystem (global scale), ecosystem (regional scale), health and wellbeing/ecosystem (regional scale) and natural resources (global scale). Module D is omitted from these figures, but tables of results that accompany these figures provided in Appendix F include module D.

6.1.1 Area of protection: ecosystem (global scale)

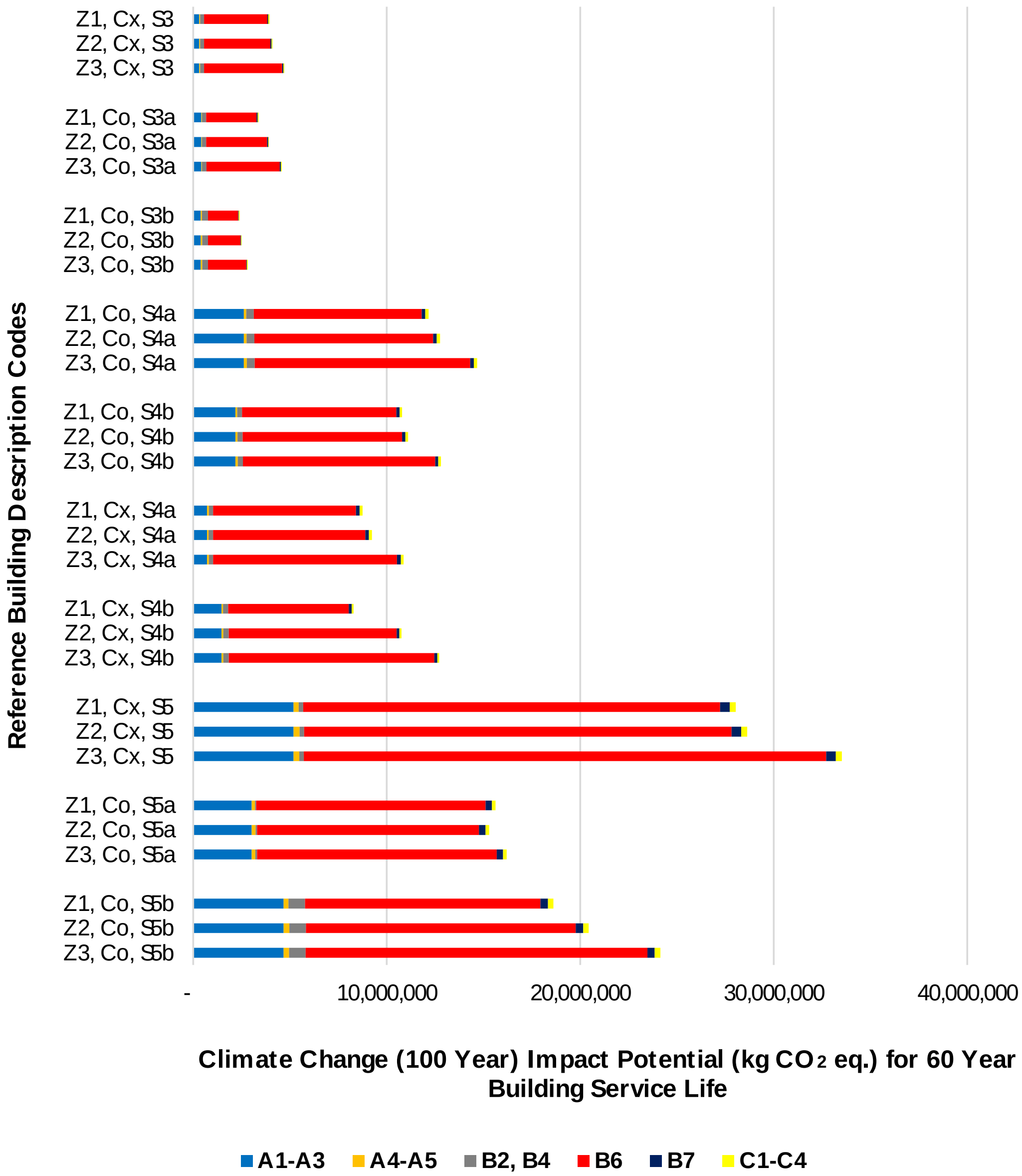


Figure 17. Total climate change indicator results over a 60-year service life.

Observations from climate change indicator results

- Module B6 operational energy is the dominant contributor to building climate change potential impacts across all reference office buildings making a contribution of 65–87%, with an average of 76%. HVAC accounts for 39% of the module B6 operational energy results and plug loads a further 28% on average across all reference office buildings (from Figure 14).
- Modules A1–A3 account for 7–25% of the calculated climate change indicator results, with an average contribution of 17%.
- All other life cycle stages combined make a contribution of 4–18% to calculated climate change indicator results, with an average of 7%.
- The results reinforce the need to focus on operational energy reduction during concept and preliminary design.
- As would be expected and mirroring the trend revealed in Figure 16, the larger buildings by size class have larger climate change indicator results. To remove the

effect of building size, it is also of interest to compare the reference office buildings using a form of normalisation based on floor area, which is set out in section 6.2.

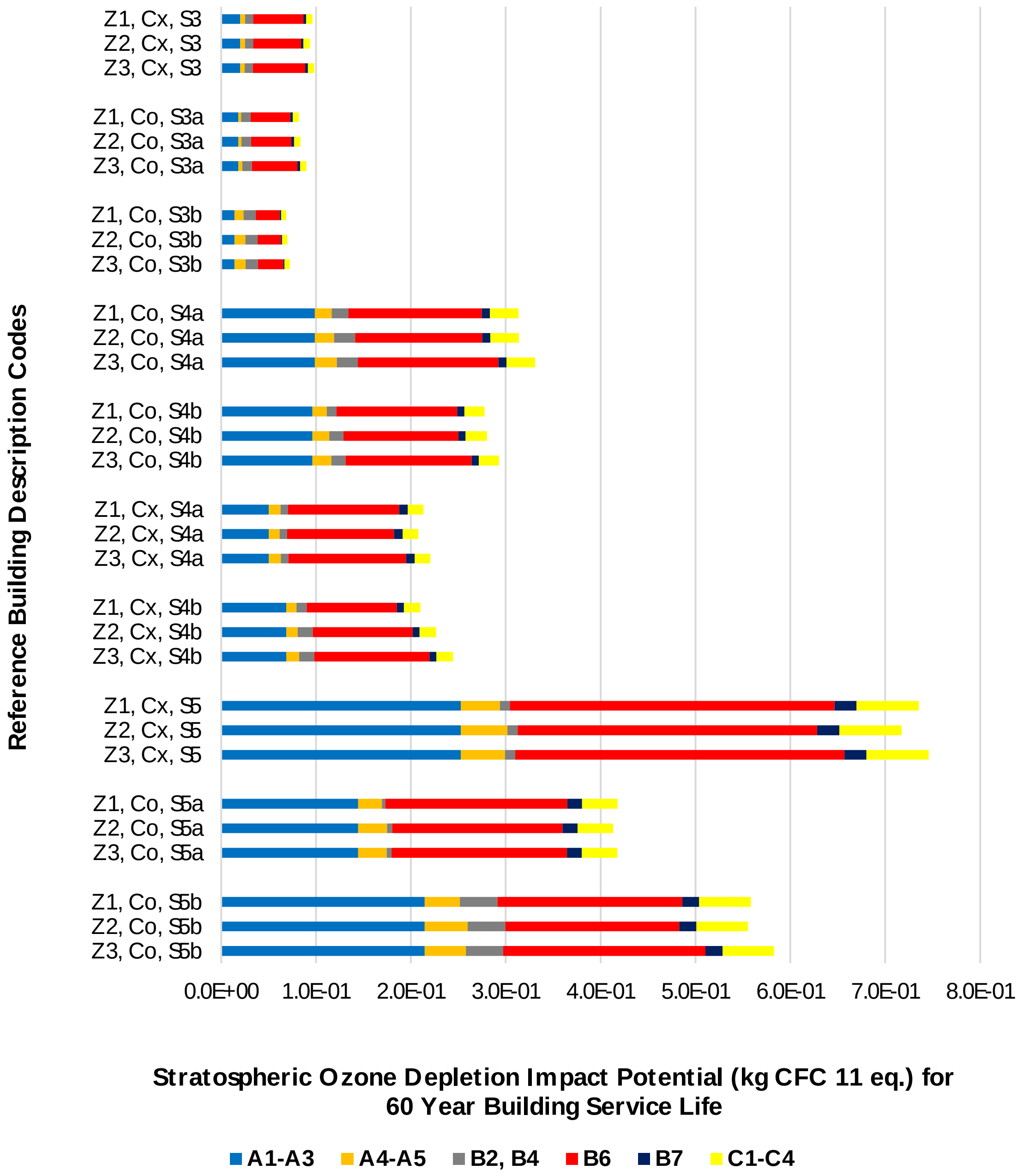


Figure 18. Total stratospheric ozone depletion indicator results over a 60-year service life.

Observations from stratospheric ozone depletion indicator results

- Calculated indicators across all reference office buildings are extremely low, which is expected given the phase-out of stratospheric ozone-depleting substances such as chlorofluorocarbons under the terms of the Montreal Protocol.
- Results do not consider fugitive emissions of refrigerants during the building life cycle. Where these refrigerants may have an ozone depletion potential (ODP), the effect of this emission over the 60-year service life is not calculated. Similarly, many of the refrigerants typically used in HVAC systems in commercial buildings have a global warming potential (GWP) and therefore contribute to climate change.

Therefore, the climate change impact associated with fugitive emissions of these refrigerants during the building life is also not included in Figure 17.

- Compared to climate change impact potential results, module B6 operational energy is less dominant. Given the small calculated result across the life cycle, specific processes using small amounts of substances with ozone-depleting properties can result in a sizeable contribution. Where underlying data used may be older, this may also be an artefact of the data used.

6.1.2 Area of protection: ecosystem (regional scale)

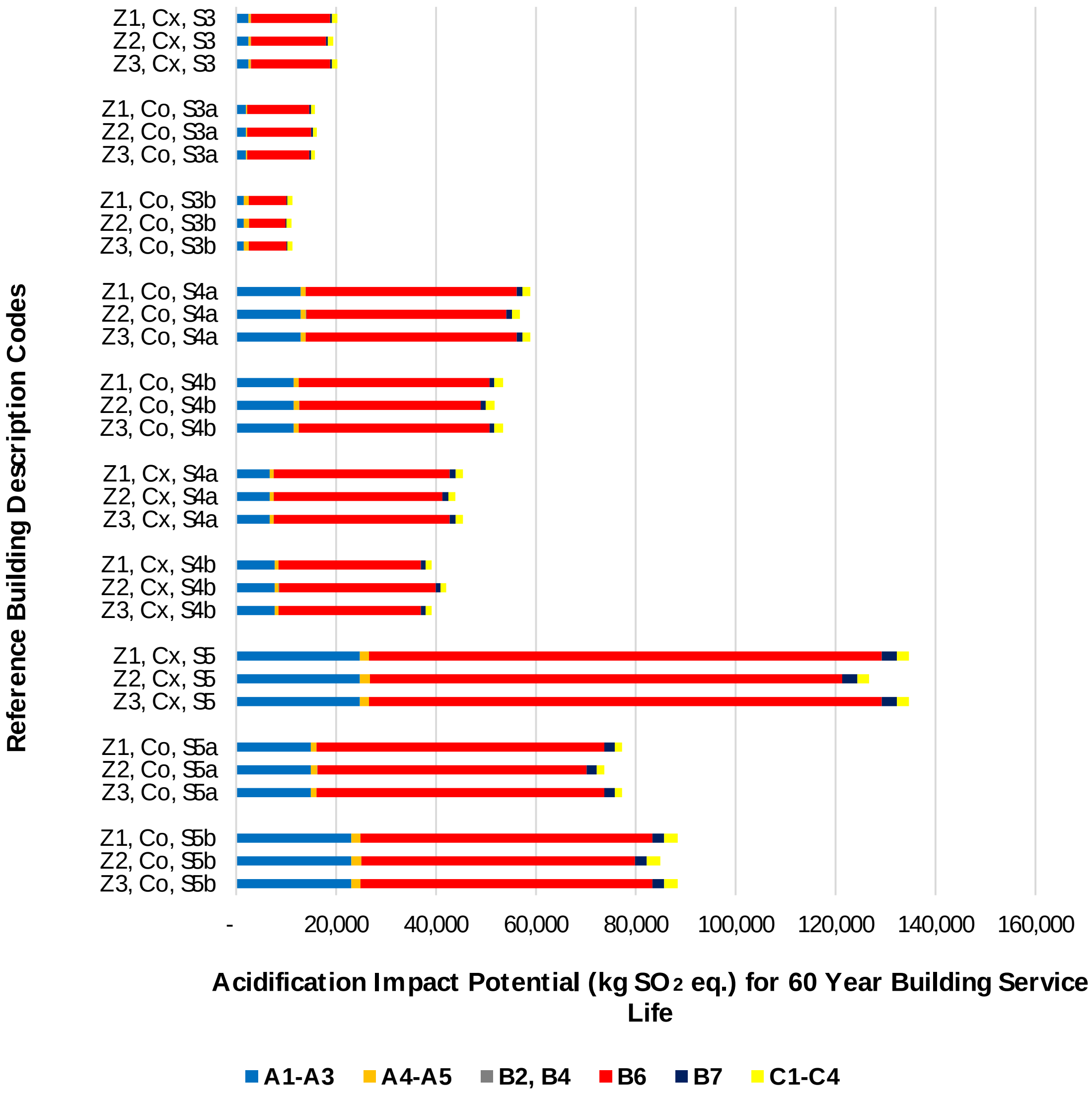


Figure 19. Total acidification indicator results over a 60-year service life.

Observations from acidification indicator results

- In a buildings context, acidification is associated with combustion of fossil fuels for generation of heat directly in buildings, to produce grid electricity or for transportation of materials.
- Module B6 dominates, with a contribution range of 65–81% and an average across the reference office buildings of 73%.
- Modules A1–A3 make a material contribution of 11–27%, with an average across the reference buildings of 20%.

- All other life cycle stages combined make a contribution of 5–20%, with an average across the reference buildings of 7%.

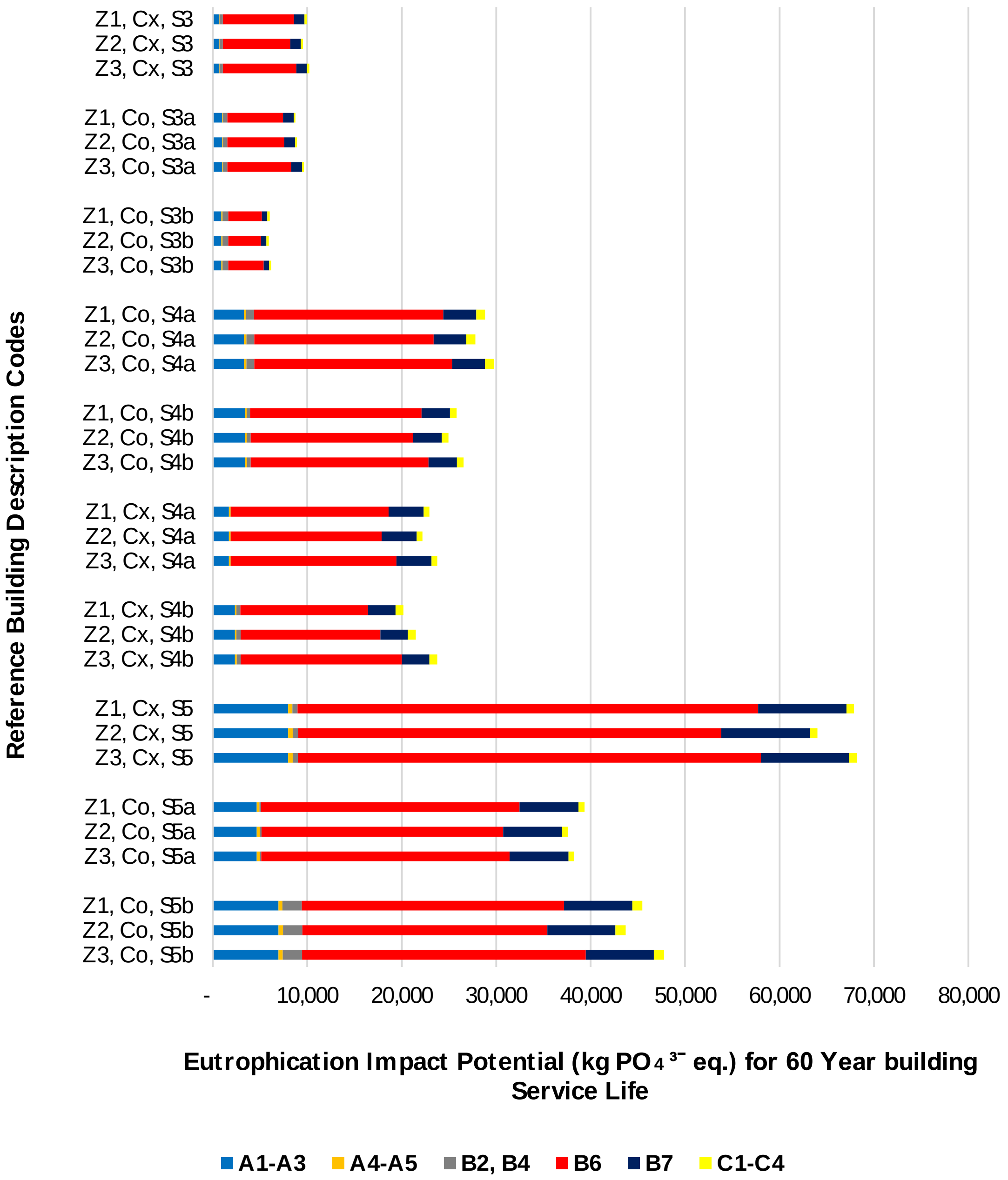


Figure 20. Total eutrophication indicator results over a 60-year service life.

Observations from eutrophication indicator results

- Module B6 operational energy dominates, contributing an average of 69% with a range of 59–76% across all reference office buildings.
- Unlike other assessed indicators in which its contribution is insignificant, module B7 operational water use contributes an average of 14% across all reference office buildings.
- Modules A1–A3 make a 12% average contribution, with a range of 6–16%.
- All other life cycle stages collectively contribute 5% to calculated eutrophication indicator results.

6.1.3 Area of protection: health and wellbeing/ecosystem (regional scale)

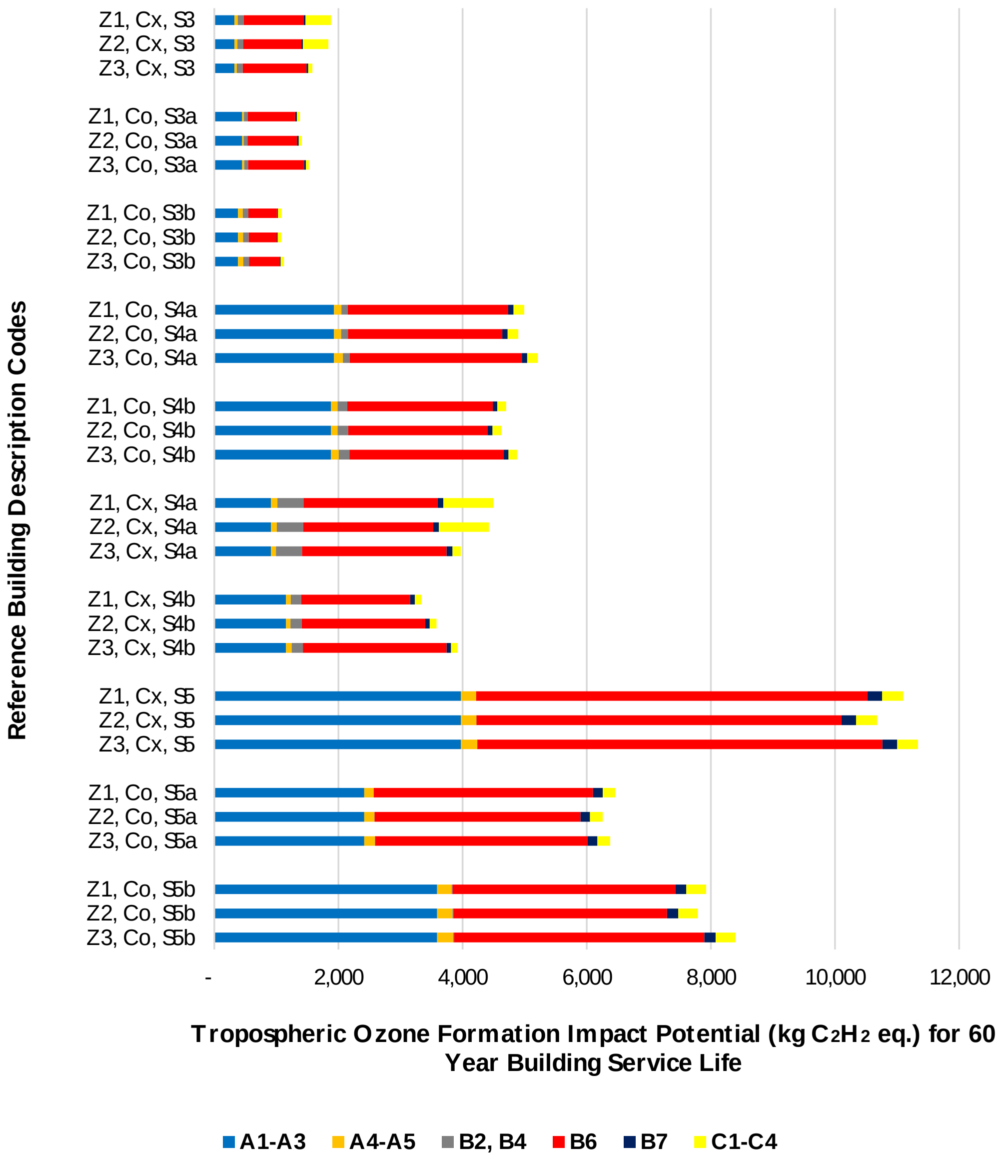


Figure 21. Total tropospheric ozone formation indicator results over a 60-year service life.

Observations from tropospheric ozone formation indicator results

- Tropospheric ozone formation (or photochemical oxidant formation) is primarily due to emissions of volatile organic compounds that arise from combustion of fossil fuels. They are therefore associated with combustion processes for heat and also in transport.
- Trends are similar to those of other indicators and include:
  - a dominant contribution from module B6 operational energy of 52%, with a spread of 42–65%
  - an important contribution from modules A1–A3, with an average of 36% and a spread of 17–46%
  - all other life cycle stages contribute a total of 12%, with a spread of 7–32%.

6.1.4 Area of protection: natural resources (global scale)

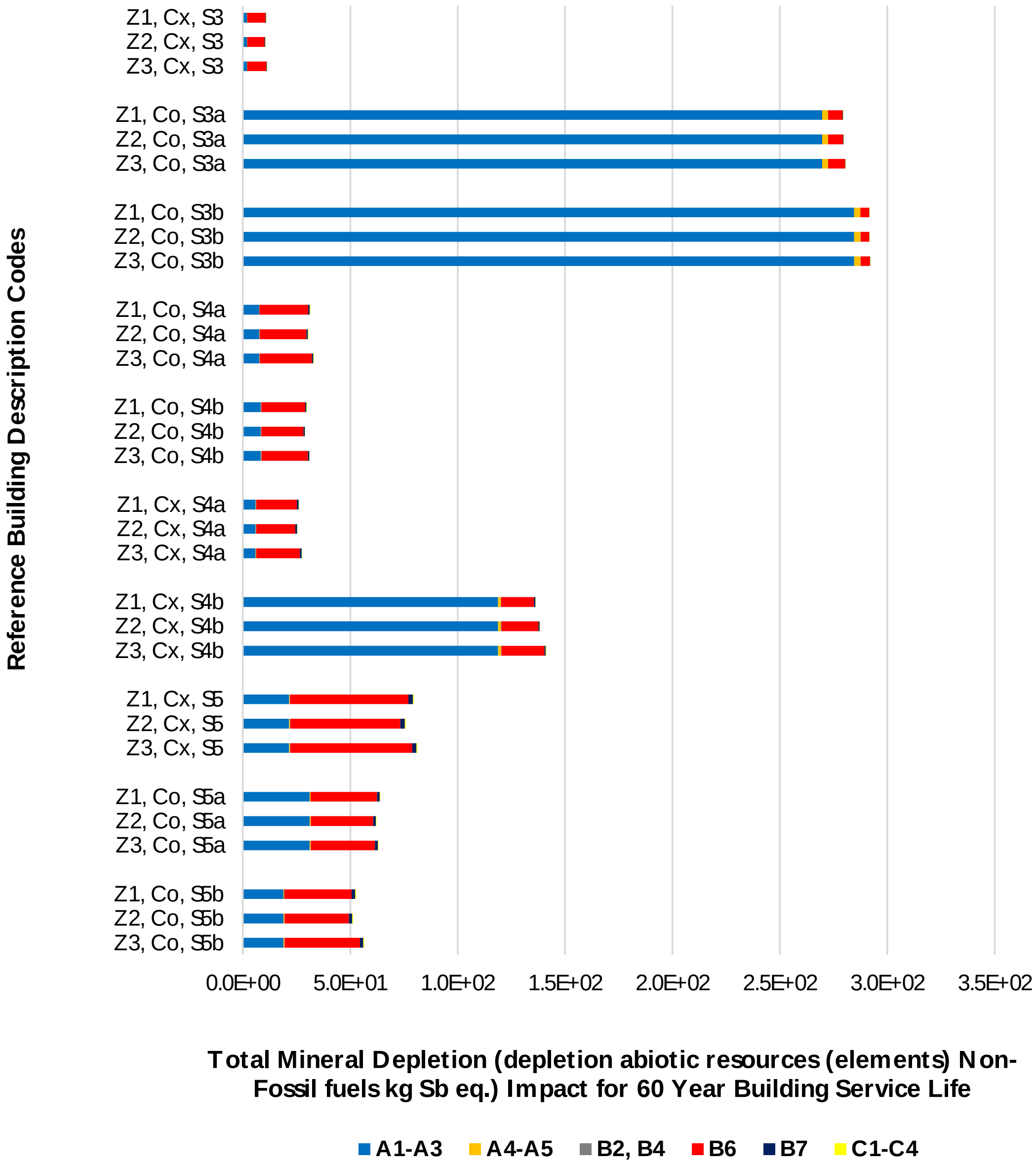


Figure 22. Total abiotic resource depletion (elements) indicator results over a 60-year service life.

Observations from abiotic resource depletion (elements) indicator results

Overall, abiotic resource depletion results for elements do not show the same trends by building size observed for other indicators, although a similar trend is observed for the module B6 operational energy results.

Total results are small (a maximum of less than 300 kg eq. Sb over 60 years), and therefore use of specific materials dominates. Those buildings showing a larger impact than others in Figure 22 appear to contain more galvanised steel, meaning the calculated abiotic resource depletion (elements) indicator for these buildings is being driven by the underlying data used to represent the material. Since no New Zealand specific data was available, it is difficult to ascertain if this elevated (but small) impact is reasonable or an artefact of the selected source of data (an EPD from a different geographical region).

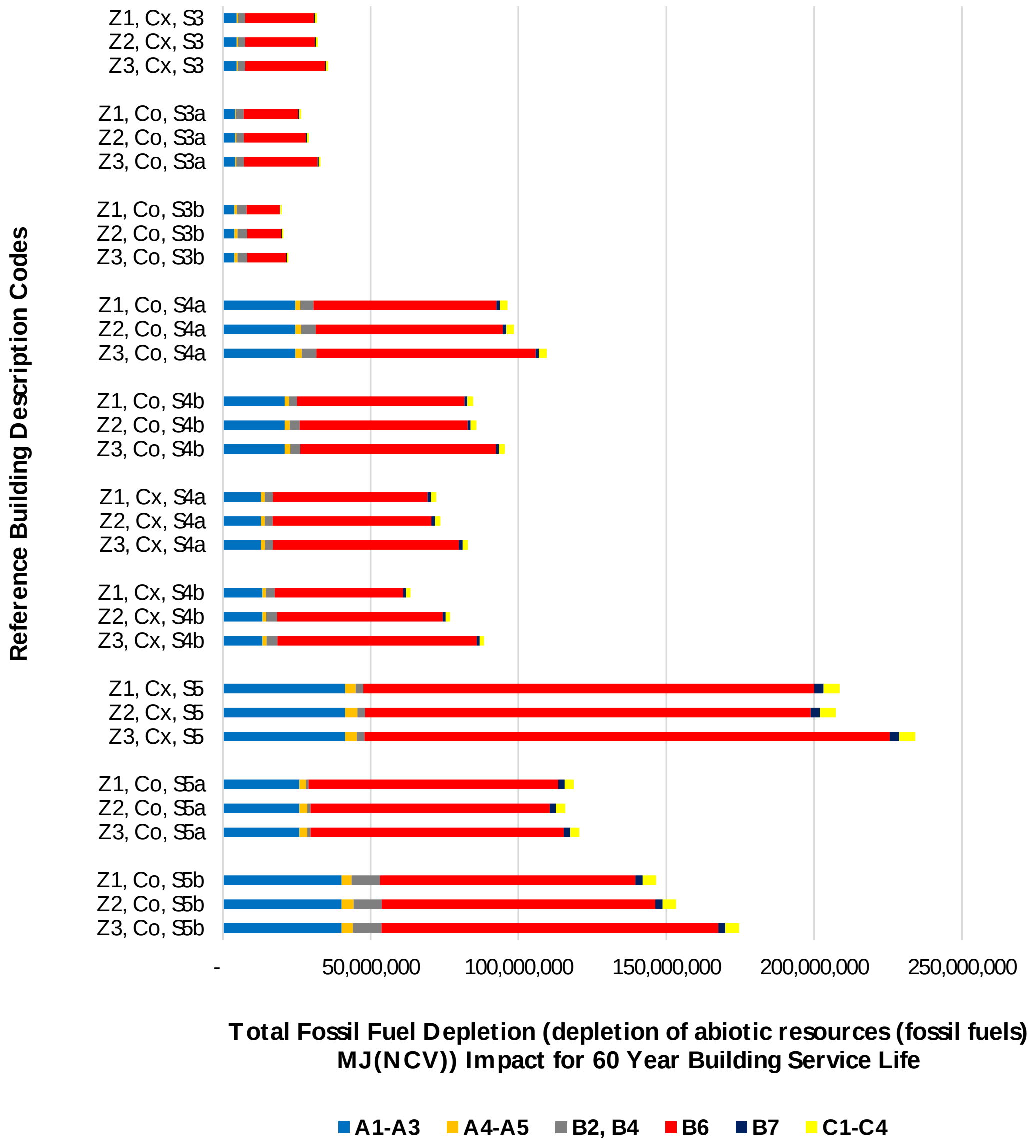


Figure 23. Total abiotic resource depletion (fossil fuels) indicator results over a 60-year service life.

Observations from abiotic resource depletion (fossil fuels) and total primary energy indicator results

Unsurprisingly, results in Figure 23 and Figure 24 closely align with results in Figure 17 and show the following:

- Module B6 contributes 69% to the abiotic resource depletion (fossil fuels) indicator with a spread of 56–76%. This compares with a 21% contribution from modules A1–A3 (and a spread of 13–27%) and a 10% contribution for all other life cycle stages (with a spread of 6–25%).
- In total primary energy terms, module B6 contributes 85% with a spread of 77–88%. The difference between the average of 85% here and the average of 69% for the fossil fuel depletion indicator (and 76% for the climate change indicator) is a reflection of the low carbon intensity of the New Zealand grid, which supplies most of the energy for module B6.

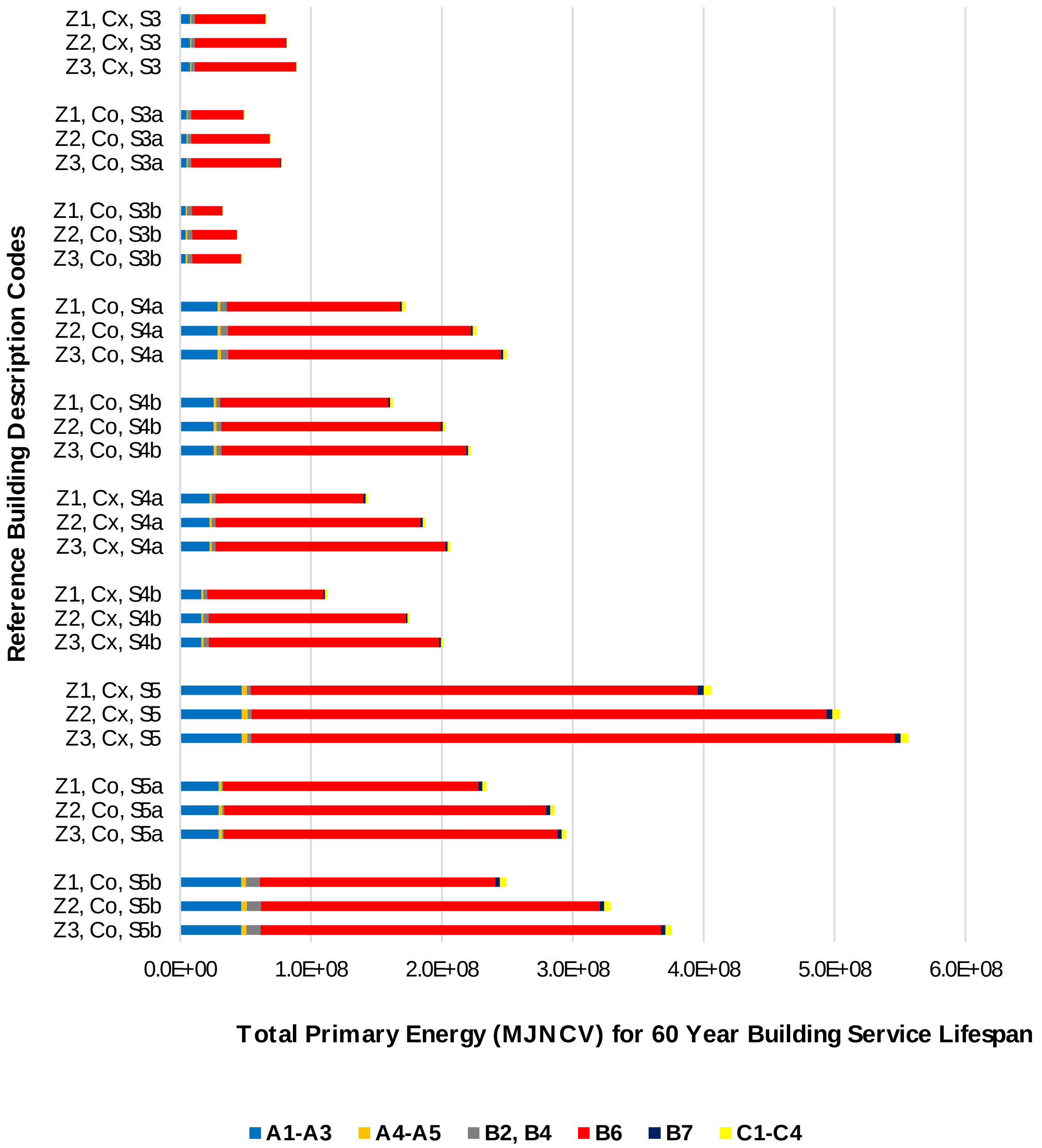


Figure 24. Total primary energy results over a 60-year service life.

- Modules A1–A3 contribute 11% to total primary energy results (with a spread of 6–14%), which is in contrast to a 21% average impact on a fossil fuel depletion impact potential basis. This is likely to reflect the greater proportion of fossil fuels directly consumed for heat during production of materials.
- All other life cycle stages contribute a total of 4% (with a spread of 3–13%) to total primary energy.

6.2 Indicators normalised by floor area (and year)

Having illustrated the difference in results between zone 1, 2 and 3 reference office buildings in section 6.1, results in this section are provided for zone 1 (Auckland) only, which is where the majority of the reference buildings are located (Table 15).

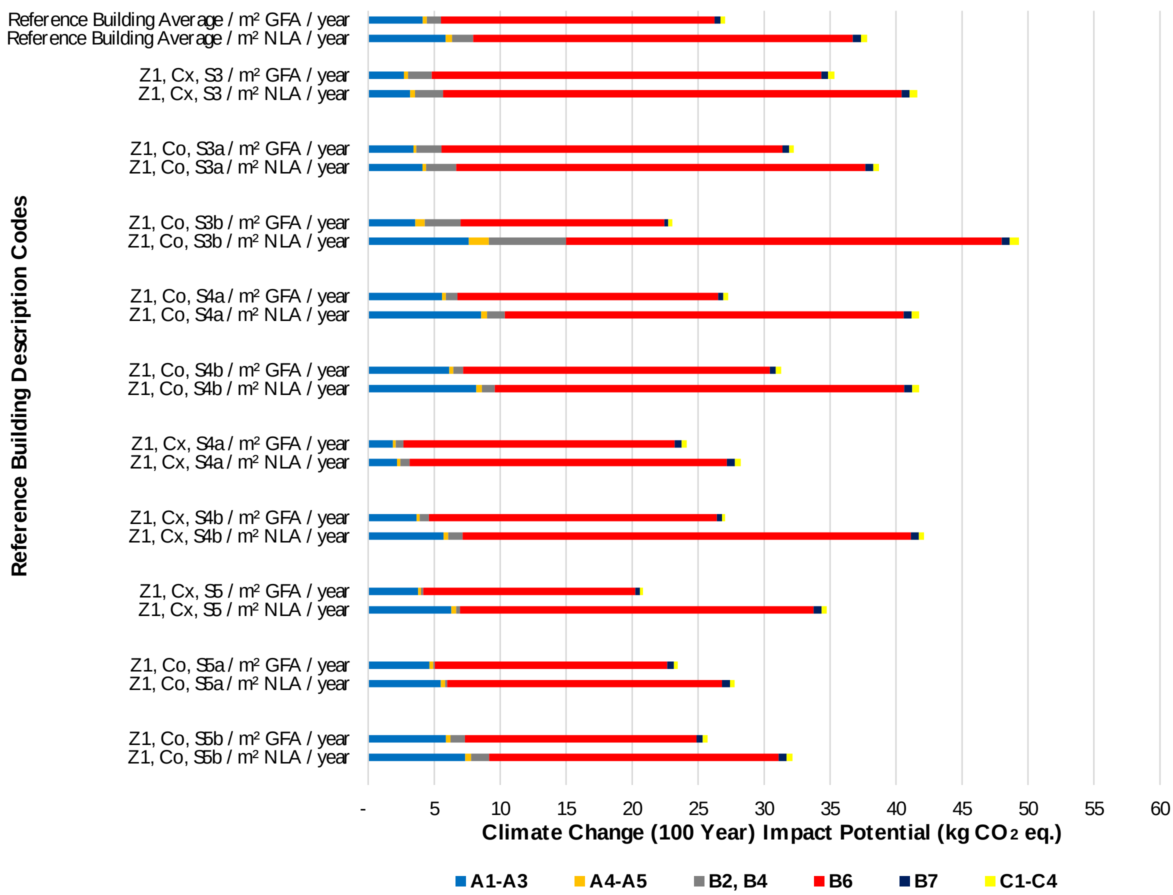
Since all reference office buildings adopt the default service life of 60 years, total results are divided by 60 to obtain per year figures.

Results are also divided by floor area using two definitions – GFA and NLA, for comparison. Floor areas for reference office buildings are provided in Table 15. Normalising for floor area allows any trends across reference office buildings of different sizes to be revealed. Units are therefore impact/floor area/year.

Given that NLA values are smaller than GFA values (from Table 15), it is unsurprising that results normalised for NLA in Figure 25 to Figure 32 are larger. The NLA excludes service areas and non-occupied building spaces such as car parks, circulation areas, hallways and atria (for example).

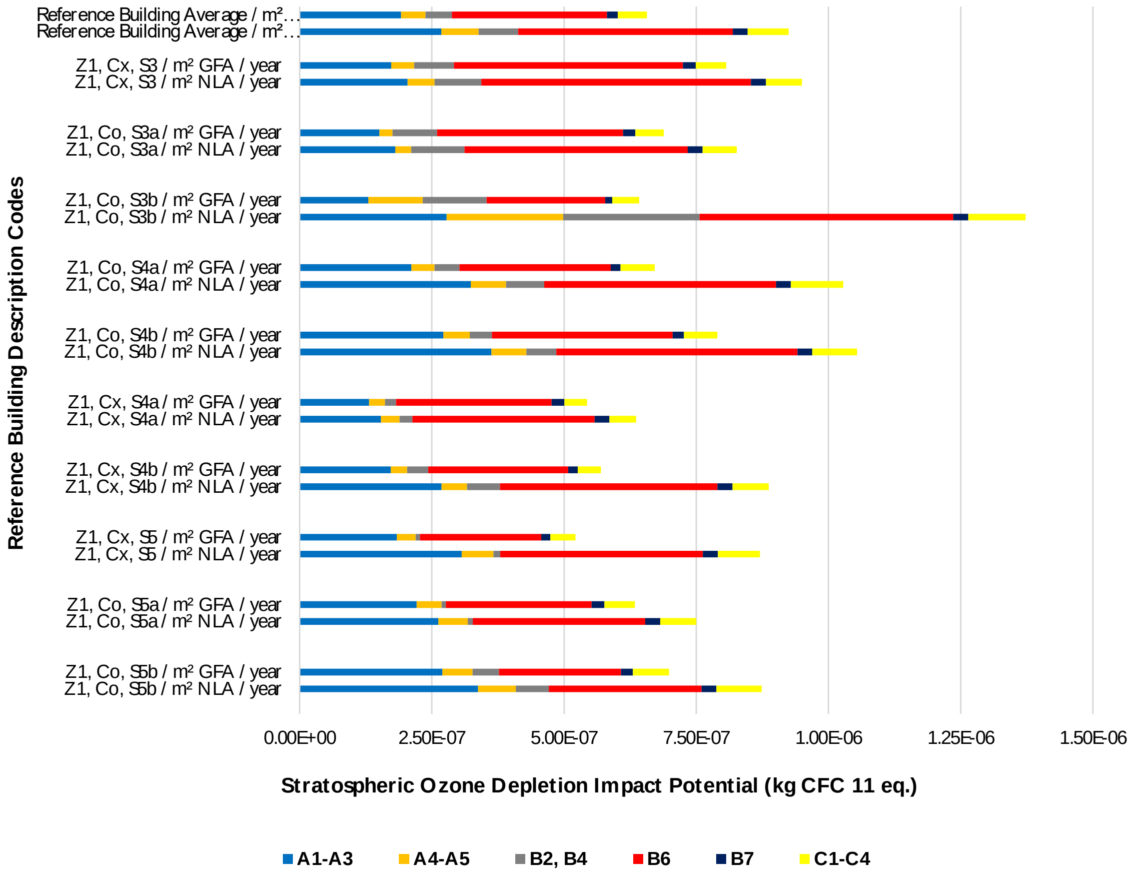
Use of the NLA as a basis for normalisation for the floor area appears preferable as it removes anomalies that might be caused by buildings with sizeable floor areas that are included in the definition of GFA but excluded from the definition of NLA. Underground car parks in buildings are an example of this. Reference office building Z1, Co, S3b in the figures below illustrates this. Due to nearly 40% (Table 15) of the building's GFA being underground car parking, there is a large difference between results expressed on an NLA and GFA basis.

6.2.1 Area of protection: ecosystem (global scale)



	kg CO_2 eq./m² GFA/year (rounded)	kg CO_2 eq./m² NLA/year (rounded)
Average of reference office buildings	27.0	37.8

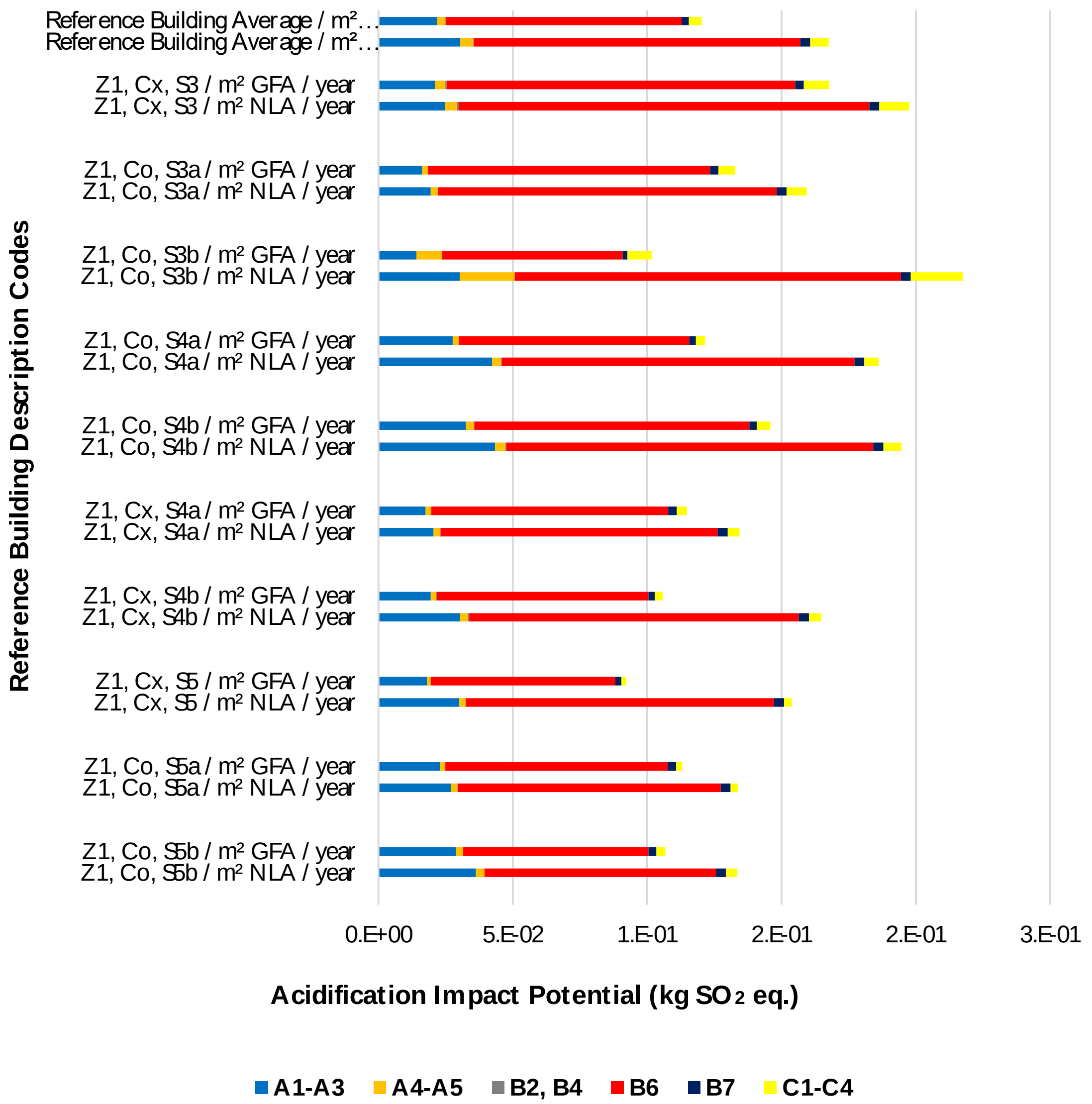
Figure 25. Climate change indicator results normalised for floor area and service life.



	kg CFC 11 eq./m² GFA/year (rounded)	kg CFC 11 eq./m² NLA/year (rounded)
Average of reference office buildings	0.0000007	0.0000009

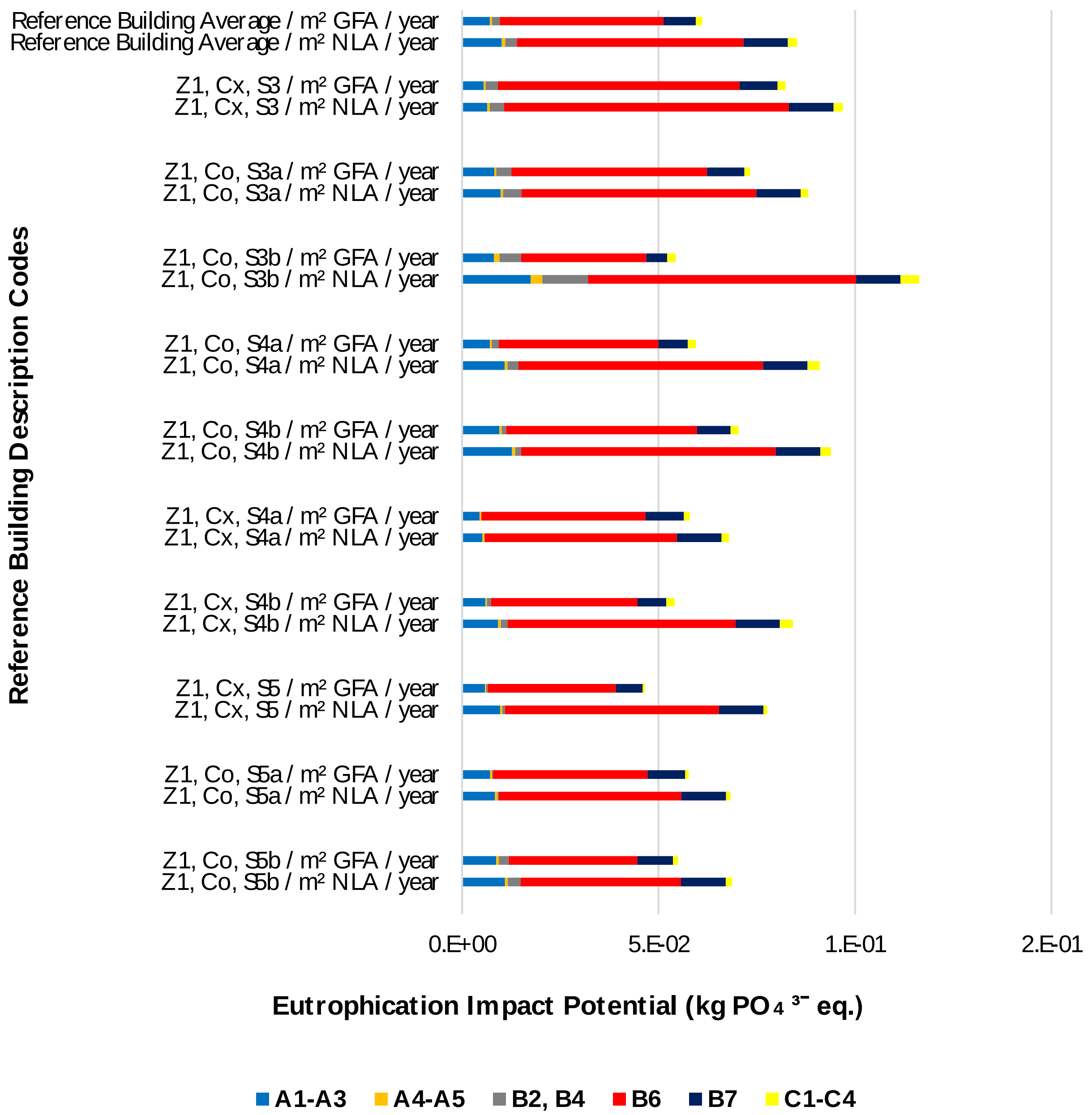
Figure 26. Stratospheric ozone depletion indicator results normalised for floor area and service life.

6.2.2 Area of protection: ecosystem (regional scale)



	kg SO_2 eq./m² GFA/year (rounded)	kg SO_2 eq./m² NLA/year (rounded)
Average of reference office buildings	0.12	0.17

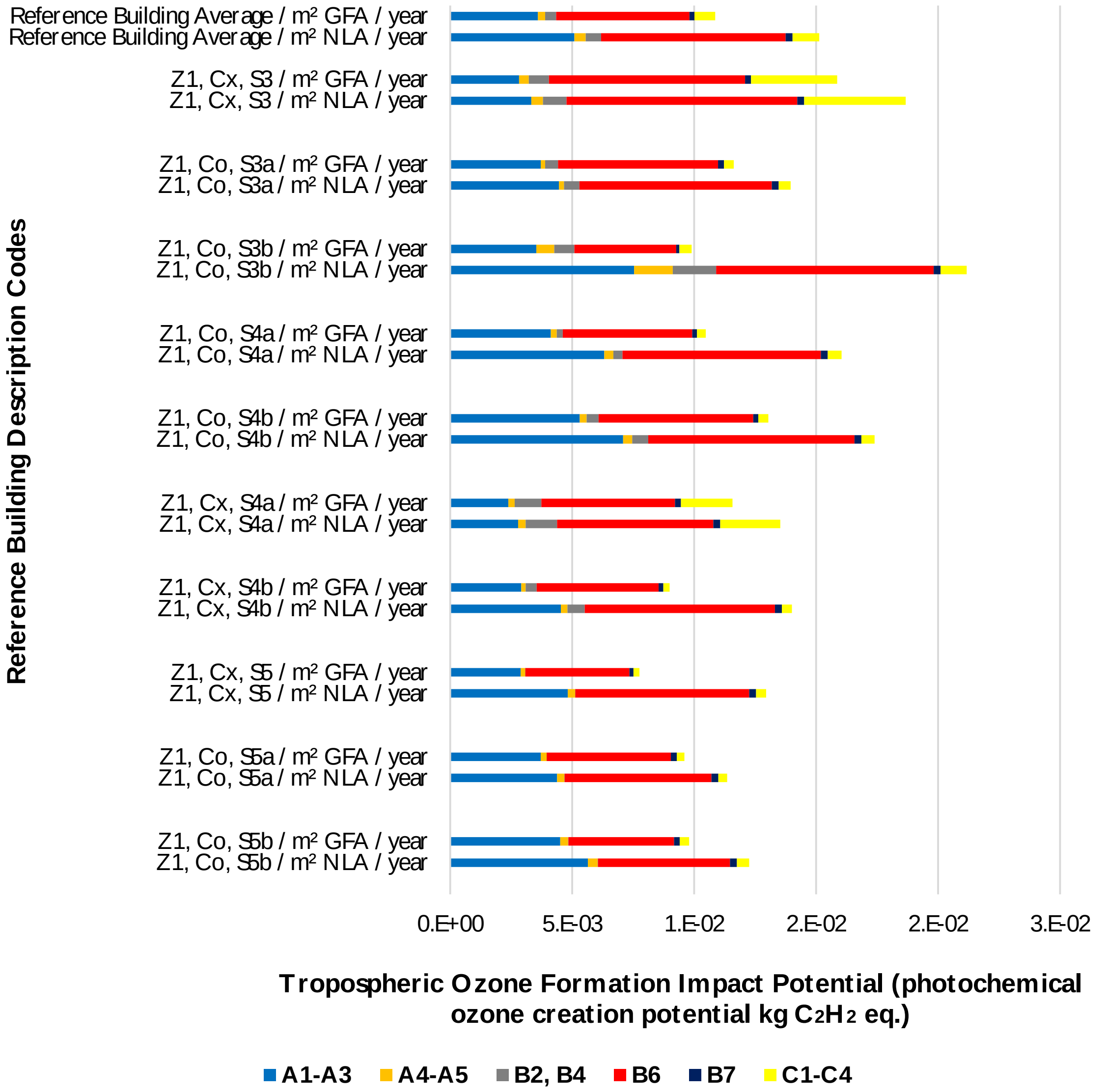
Figure 27. Acidification indicator results normalised for floor area and service life.



	kg PO_4^{3-} eq./m² GFA/year (rounded)	kg PO_4^{3-} eq./m² NLA/year (rounded)
Average of reference office buildings	0.061	0.085

Figure 28. Eutrophication indicator results normalised for floor area and service life.

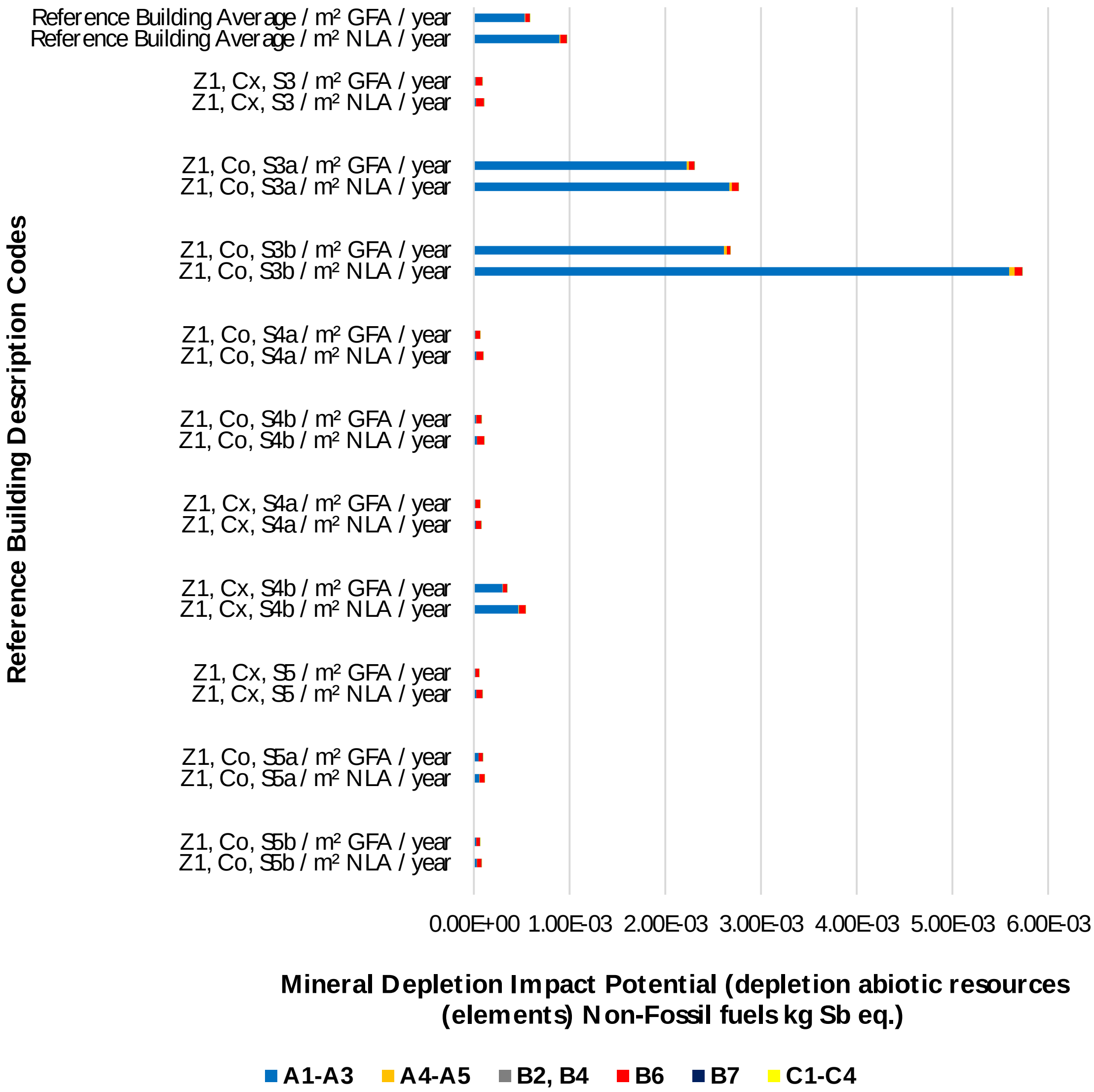
6.2.3 Area of protection: health and wellbeing/ecosystem (regional scale)



	kg C_2H_2/m^2 GFA/year (rounded)	kg C_2H_2/m^2 NLA/year (rounded)
Average of reference office buildings	0.011	0.015

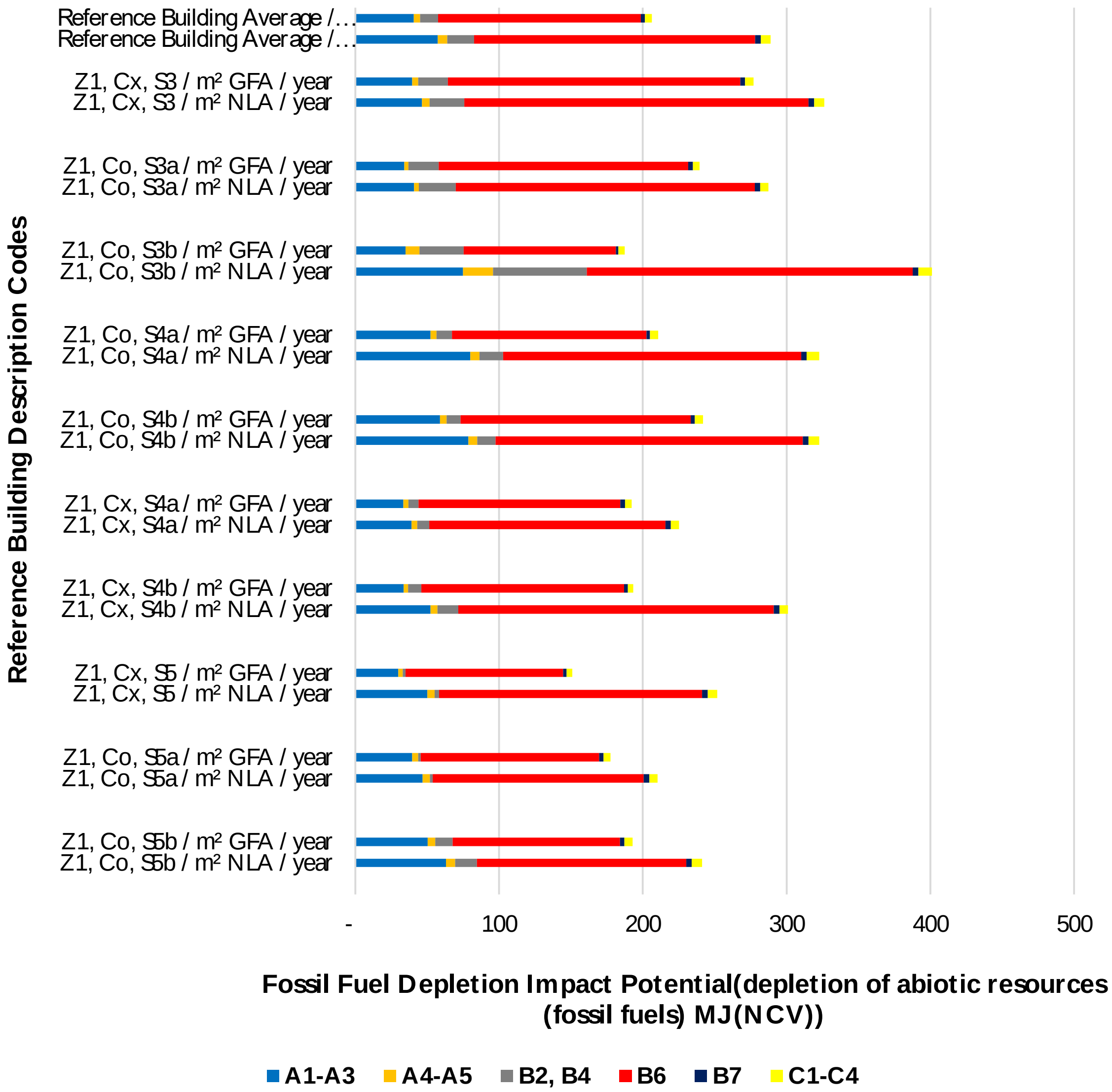
Figure 29. Tropospheric ozone formation indicator results normalised for floor area and service life.

6.2.4 Area of protection: natural resources (global scale)



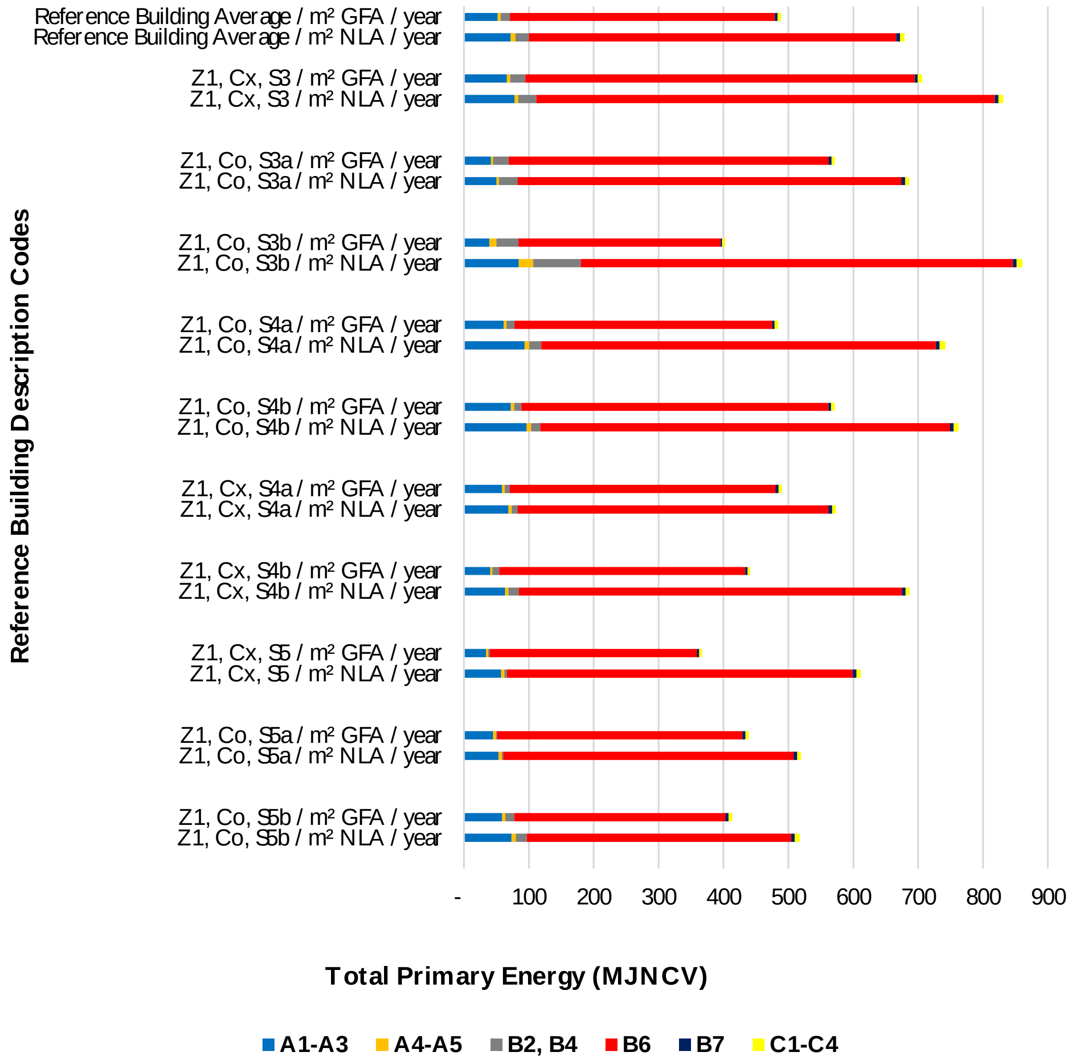
	kg Sb eq./m² GFA/year (rounded)	kg Sb eq./m² NLA/year (rounded)
Average of reference office buildings	7.41E-05	9.70E-05

Figure 30. Abiotic resource depletion (elements) indicator results normalised for floor area and service life.



	MJ/m² GFA/year (rounded)	MJ/m² NLA/year (rounded)
Average of reference office buildings	206	271

Figure 31. Abiotic resource depletion (fossil fuels) indicator results normalised for floor area and service life.



	MJ (NCV)/m² GFA/year	MJ (NCV)/m² NLA/year
Average of reference office buildings	496	651

Figure 32. Total primary energy normalised for floor area and service life.

6.3 Results by indicator

Results in this section are presented on an impact/m^2 NLA/year basis. Each indicator is divided into three subsections, displaying results according to:

- building activity (Co and Cx)
- building size (size class 3, 4 and 5).
- structural system (braced frame, post-tension system and rigid frame).

Abiotic resource depletion (elements) results are not provided due to the dominance of the data effect observed in section 6.1.4. Observed trends are as follows:

- Climate change and abiotic resource depletion (fossil fuels) impacts and total primary energy show higher module B6 operational energy for Cx compared to Co. This may be due to higher demand for electricity from other activities in the Cx buildings (for example, from cafés or gyms) compared to electricity use in offices. The trend is not as apparent for impacts such as acidification and eutrophication, which show little difference.

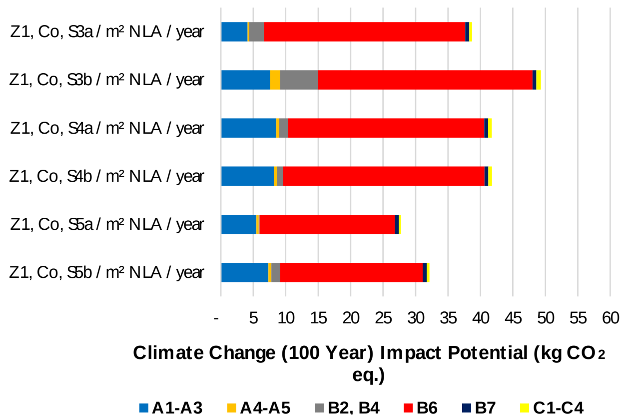
- When compared based on size class, the greater module A1–A3 impacts apparent for larger buildings in terms of totals over 60 years are no longer apparent when normalised according to NLA.
- Larger reference office buildings typically show lower impacts compared with smaller reference office buildings when normalised based on NLA. This arises primarily due to differences in module B6 operational energy and is likely to be due to a reduction in building HVAC demands, in particular, cooling loads, due to deeper floor plate depths resulting in less external solar gains.
- In general, no structural system appears to have consistently lower indicator values in comparison with alternatives. The post-tensioned systems have lower climate change and abiotic resource depletion (fossil fuels) indicator results but appear to have a higher tropospheric ozone formation indicator result. Acidification and eutrophication impacts show no discernible differences between the three structural systems.

6.3.1 Area of protection: ecosystem (global scale)

6.3.1.1 Climate change (100 year)

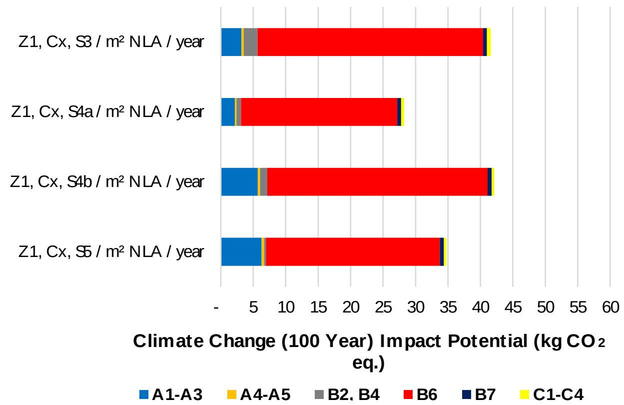
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 39 kg CO_2 eq.
A1–A3 Average 7 kg CO_2 eq. 18%
B6 Average 28 kg CO_2 eq. or 73%
Others Average 4 kg CO_2 10%

Building Activity: Commercial Mixed

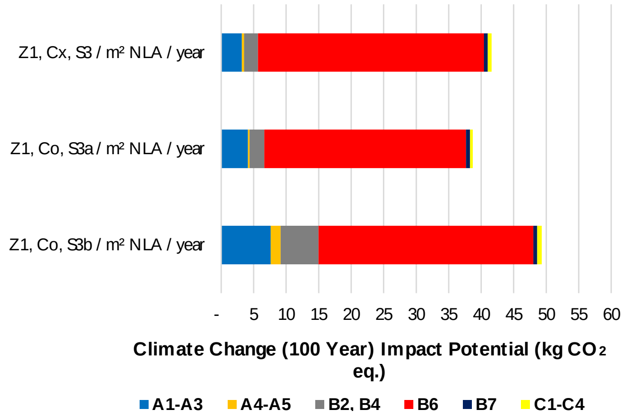


Total Average 37 kg CO_2 eq.
A1–A3 Average 4 kg CO_2 eq. 12%
B6 Average 30 kg CO_2 eq. or 82%
Others Average 2 kg CO_2 7%

Figure 33. Climate change indicator results by building activity.

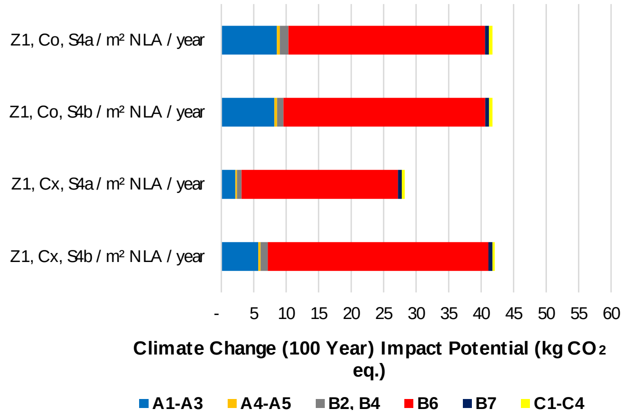
Units per m² NLA/year

Size class 3



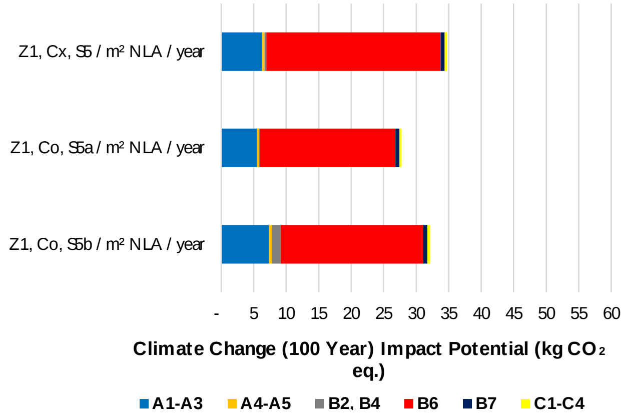
Total Average 43 kg CO_2 eq.
A1–A3 Average 5 kg CO_2 eq. 12%
B6 Average 33 kg CO_2 eq. 76%
Others Average 5 kg CO_2 eq. 12%

Size class 4



Total Average 38 kg CO_2 eq.
A1–A3 Average 6 kg CO_2 eq. 16%
B6 Average 30 kg CO_2 eq. 78%
Others Average 2 kg CO_2 eq. 6%

Size class 5

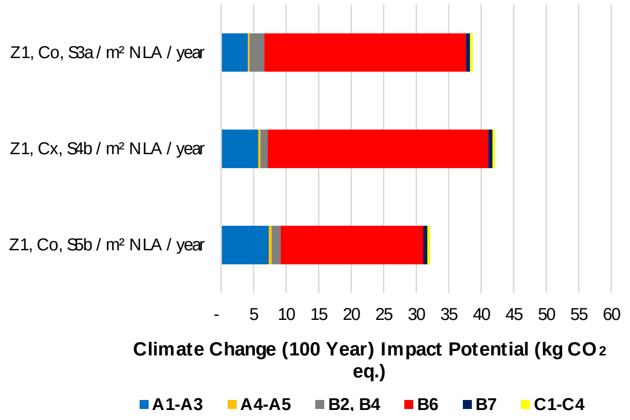


Total Average 32 kg CO_2 eq.
A1–A3 Average 6 kg CO_2 eq. 20%
B6 Average 23 kg CO_2 eq. 74%
Others Average 2 kg CO_2 eq. 6%

Figure 34. Climate change indicator results by building size.

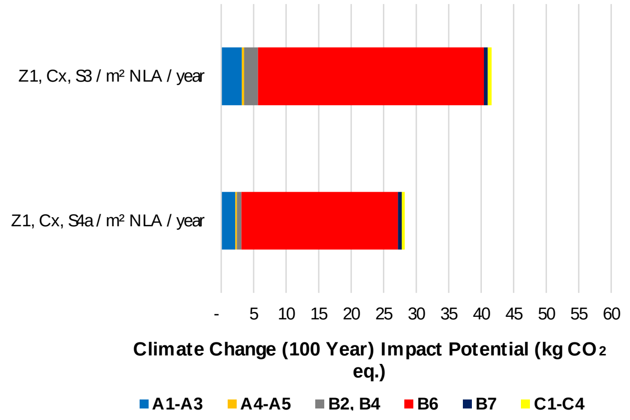
Units per m² NLA/year

Braced frame



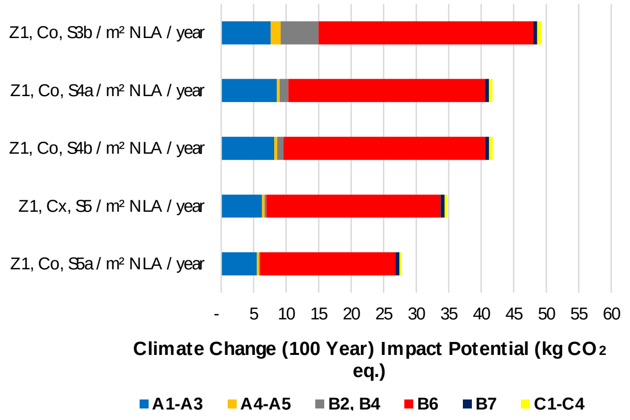
Total Average 38 kg CO_2 eq.
A1–A3 Average 6 kg CO_2 eq. 15%
B6 Average 29 kg CO_2 eq. 77%
Others Average 3 kg CO_2 eq. 8%

Post Tension



Total Average 35 kg CO_2 eq.
A1–A3 Average 3 kg CO_2 eq. 8%
B6 Average 29 kg CO_2 eq. 84%
Others Average 3 kg CO_2 eq. 8%

Rigid Frame



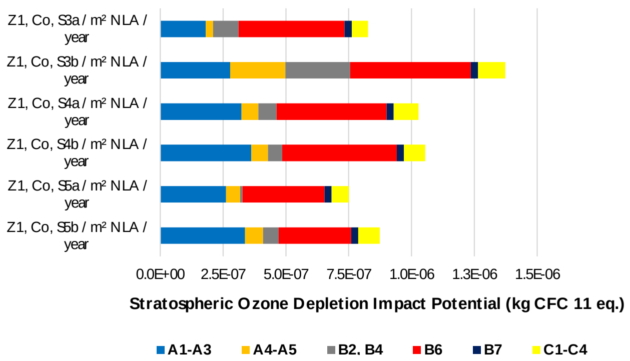
Total Average 39 kg CO_2 eq.
A1–A3 Average 7 kg CO_2 eq. 19%
B6 Average 29 kg CO_2 eq. 73%
Others Average 3 kg CO_2 eq. 9%

Figure 35. Climate change indicator results by structural system.

6.3.1.2 Stratospheric ozone depletion

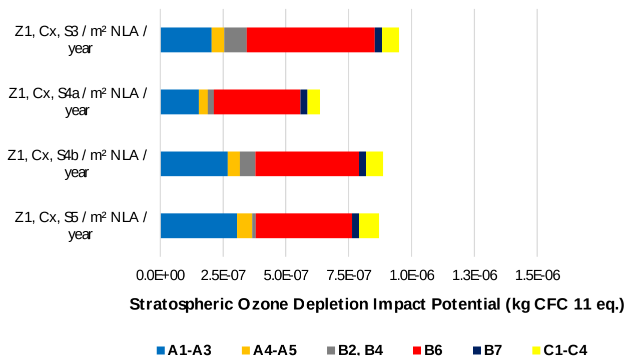
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 9.8E-7 kg CFC 11 eq.
A1–A3 Average 2.9 E-7 kg CFC 11 eq. 30%
B6 Average 4.0 E-7 kg CFC 11 eq. 41%
Others Average 2.9 E-7 kg CFC 11 eq. 30%

Building Activity: Commercial Mixed

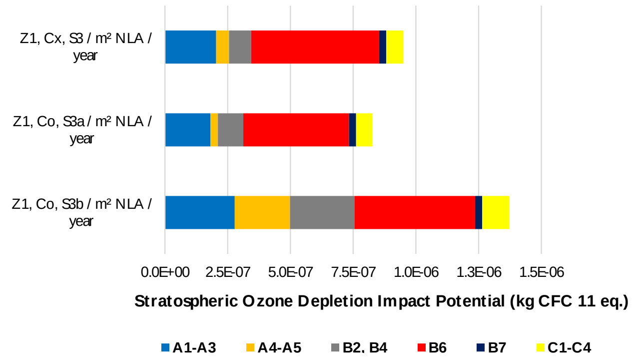


Total Average 8.4 E-7 kg CFC 11 eq.
A1–A3 Average 2.3 E-7 kg CFC 11 eq. 28%
B6 Average 4.1 E-7 kg CFC 11 eq. 49%
Others Average 1.9 E-7 kg CFC 11 eq. 23%

Figure 36. Stratospheric ozone depletion indicator results by building activity.

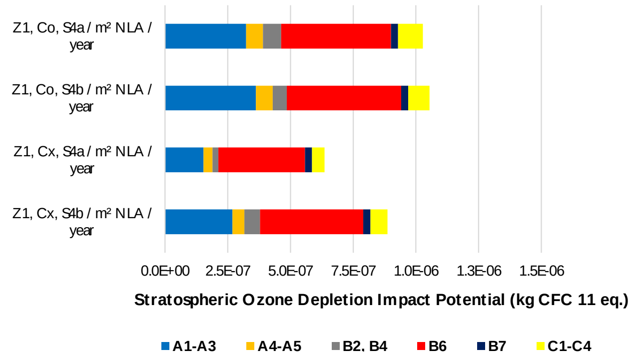
Units per m² NLA/year

Size class 3



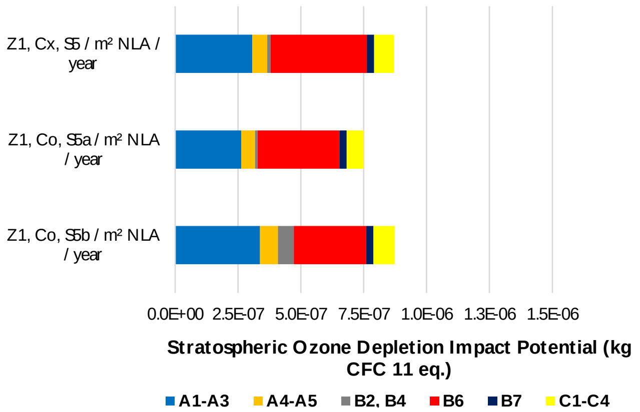
Total Average 10.5 E-7 kg CFC 11 eq.
A1–A3 Average 2.2 E-7 kg CFC 11 eq. 21%
B6 Average 4.7 E-7 kg CFC 11 eq. 45%
Others Average 3.6 E-7 kg CFC 11 eq. 34%

Size class 4



Total Average 9.0 E-7 kg CFC 11 eq.
A1–A3 Average 2.8 E-7 kg CFC 11 eq. 31%
B6 Average 4.1 E-7 kg CFC 11 eq. 46%
Others Average 2.1 E-7 kg CFC 11 eq. 23%

Size class 5

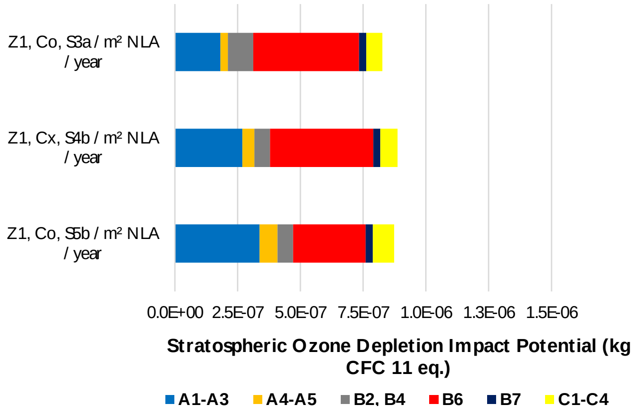


Total Average 8.3 E-7 kg CFC 11 eq.
A1–A3 Average 3.0 E-7 kg CFC 11 eq. 36%
B6 Average 3.3 E-7 kg CFC 11 eq. 40%
Others Average 2.0 E-7 kg CFC 11 eq. 24%

Figure 37. Stratospheric ozone depletion indicator results by building size.

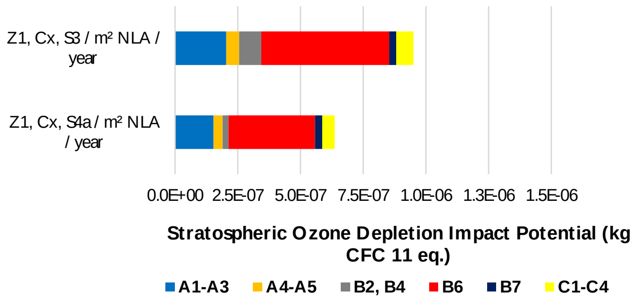
Units per m² NLA/year

Braced frame



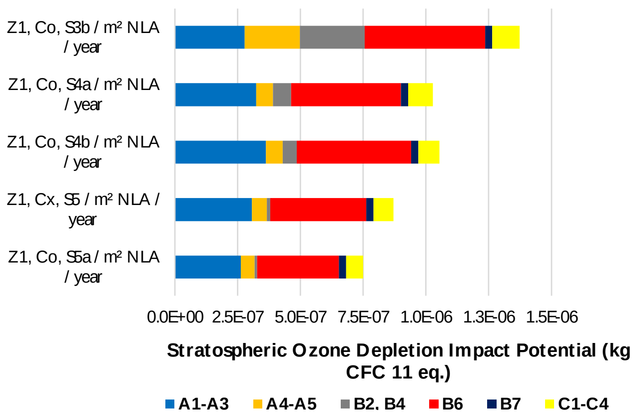
Total Average 8.6 E-7 kg CFC 11 eq.
A1–A3 Average 2.6 E-7 kg CFC 11 eq. 30%
B6 Average 3.7 E-7 kg CFC 11 eq. 43%
Others Average 2.3 E-7 kg CFC 11 eq. 26%

Post Tension



Total Average 7.9 E-7 kg CFC 11 eq.
A1–A3 Average 1.8 E-7 kg CFC 11 eq. 23%
B6 Average 4.3 E-7 kg CFC 11 eq. 54%
Others Average 1.9 E-7 kg CFC 11 eq. 24%

Rigid Frame



Total Average 10.2 E-7 kg CFC 11 eq.
A1–A3 Average 3.1 E-7 kg CFC 11 eq. 30%
B6 Average 4.2 E-7 kg CFC 11 eq. 41%
Others Average 2.9 E-7 kg CFC 11 eq. 29%

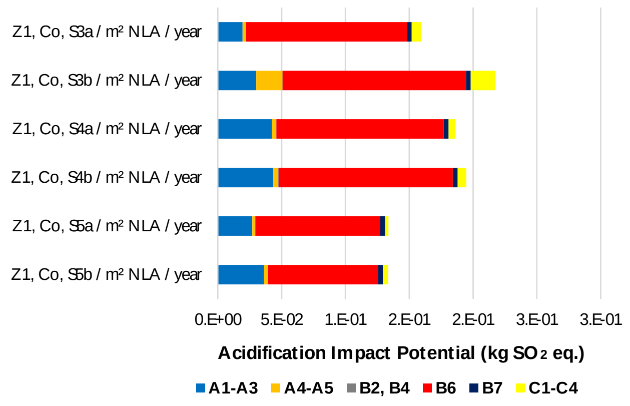
Figure 38. Stratospheric ozone depletion indicator results by structural system.

6.3.2 Area of protection: ecosystem (regional scale)

6.3.2.1 Acidification

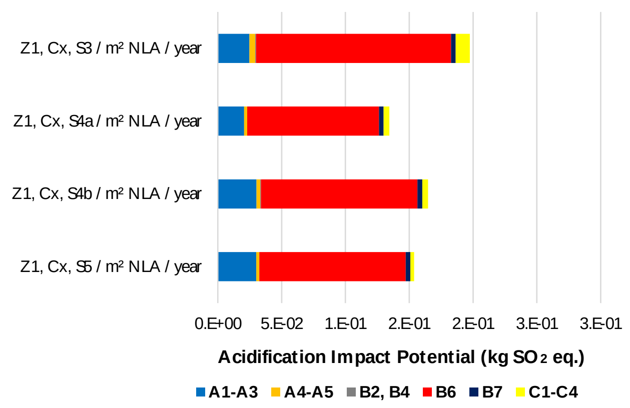
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 0.17 kg SO2 eq.
A1–A3 Average 0.03 kg SO2 eq. 19%
B6 Average 0.12 kg SO2 eq. or 70%
Others Average 0.02 kg SO2 eq. 10%

Building Activity: Commercial Mixed

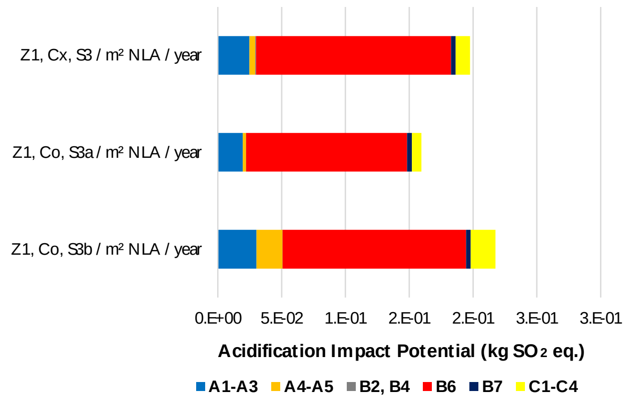


Total Average 0.16 kg SO2 eq.
A1–A3 Average 0.03 kg SO2 eq. 16%
B6 Average 0.12 kg SO2 eq. 76%
Others Average 0.01 kg SO2 eq. 8%

Figure 39. Acidification indicator results by building activity.

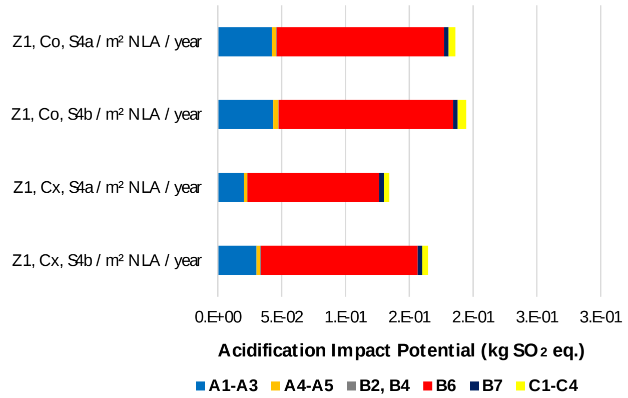
Units per m² NLA/year

Size class 3



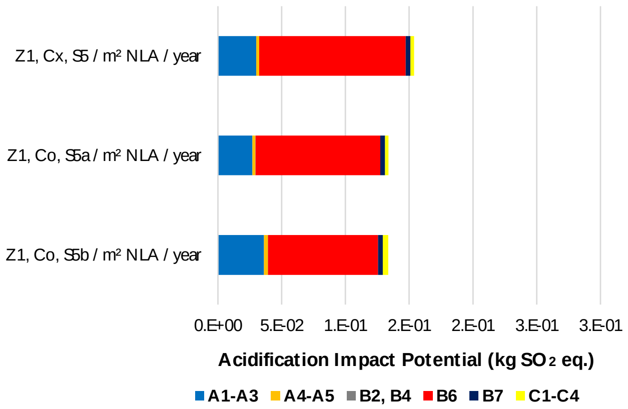
Total Average 0.19 kg SO_2 eq.
A1–A3 Average 0.02 kg SO_2 eq. 13%
B6 Average 0.14 kg SO_2 eq. 74%
Others Average 0.03 kg SO_2 eq. 13%

Size class 4



Total Average 0.17 kg SO_2 eq.
A1–A3 Average 0.03 kg SO_2 eq. 20%
B6 Average 0.12 kg SO_2 eq. 73%
Others Average 0.01 kg SO_2 eq. 7%

Size class 5

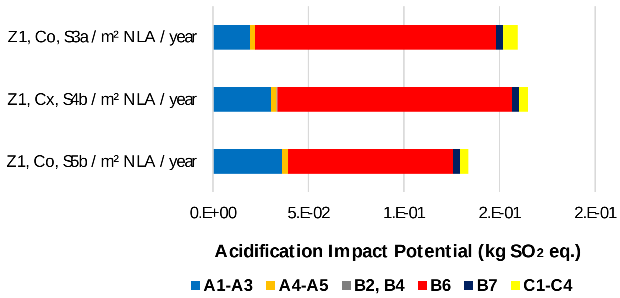


Total Average 0.14 kg SO_2 eq.
A1–A3 Average 0.03 kg SO_2 eq. 22%
B6 Average 0.10 kg SO_2 eq. 71%
Others Average 0.01 kg SO_2 eq. 7%

Figure 40. Acidification indicator results by building size.

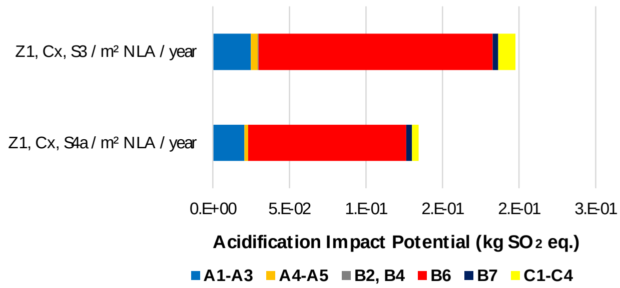
Units per m² NLA/year

Braced frame



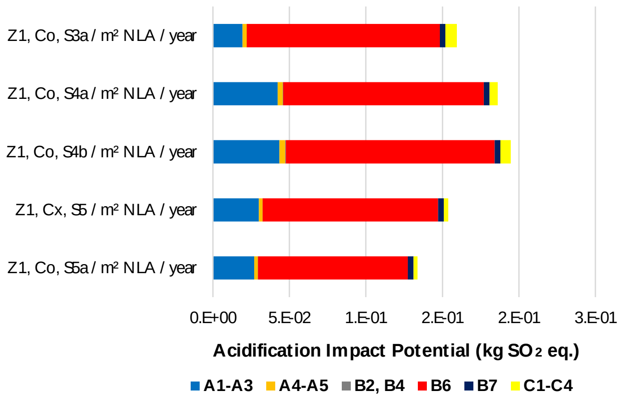
Total Average 0.15 kg SO_2 eq.
A1–A3 Average 0.03 kg SO_2 eq. 19%
B6 Average 0.11 kg SO_2 eq. 73%
Others Average 0.01 kg SO_2 eq. 8%

Post Tension



Total Average 0.17 kg SO_2 eq.
A1–A3 Average 0.02 kg SO_2 eq. 14%
B6 Average 0.13 kg SO_2 eq. 77%
Others Average 0.02 kg SO_2 eq. 9%

Rigid Frame



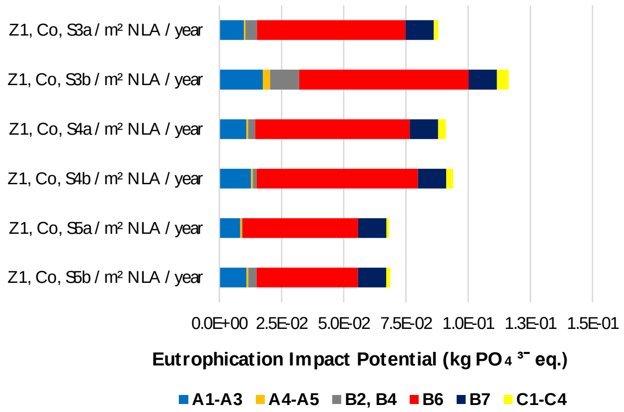
Total Average 0.18 kg SO_2 eq.
A1–A3 Average 0.03 kg SO_2 eq. 20%
B6 Average 0.12 kg SO_2 eq. 70%
Others Average 0.02 kg SO_2 eq. 10%

Figure 41. Acidification indicator results by structural system.

6.3.2.2 Eutrophication

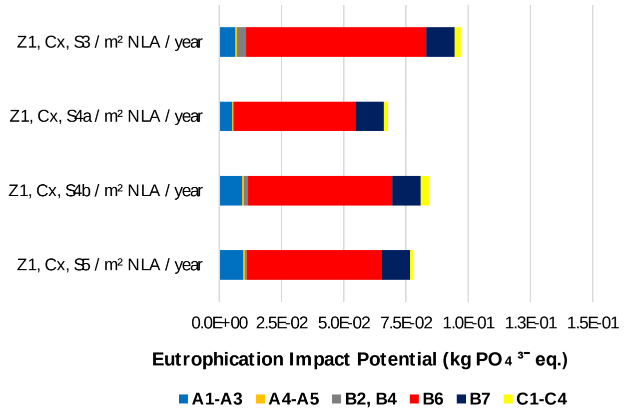
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 0.09 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 13%
B6 Average 0.06 kg PO_4^{3-} eq. 65%
Others Average 0.02 kg PO_4^{3-} eq. 22%

Building Activity: Commercial Mixed

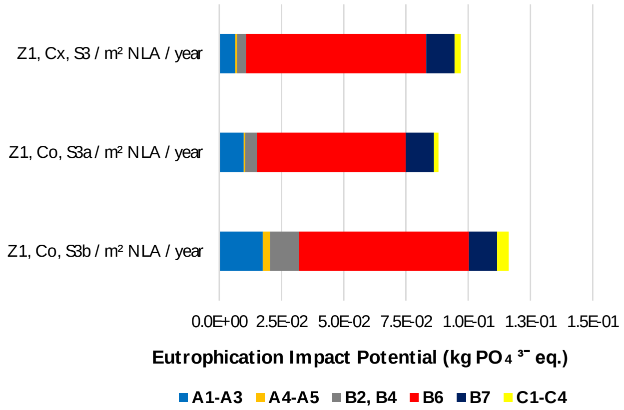


Total Average 0.08 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 9%
B6 Average 0.06 kg PO_4^{3-} eq. 72%
Others Average 0.02 kg PO_4^{3-} eq. 19%

Figure 42. Eutrophication indicator results by building activity.

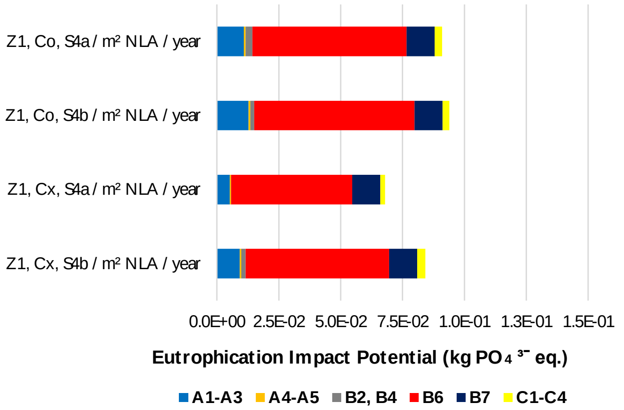
Units per m² NLA/year

Size class 3



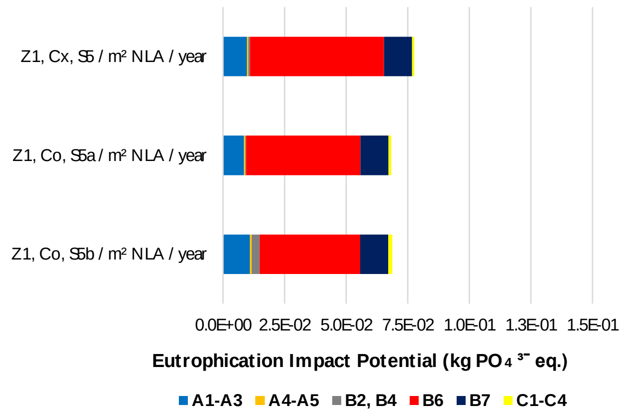
Total Average 0.10 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 11%
B6 Average 0.07 kg PO_4^{3-} eq. 67%
Others Average 0.02 kg PO_4^{3-} eq. 22%

Size class 4



Total Average 0.08 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 11%
B6 Average 0.06 kg PO_4^{3-} eq. 69%
Others Average 0.02 kg PO_4^{3-} eq. 19%

Size class 5

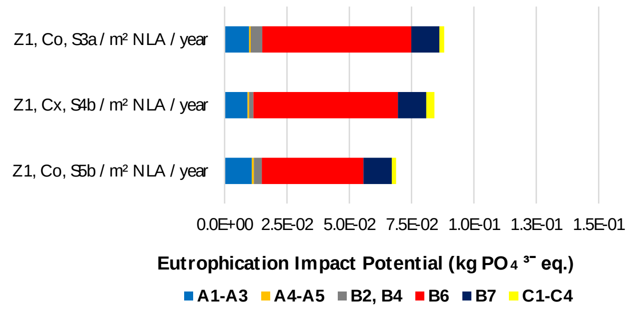


Total Average 0.07 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 14%
B6 Average 0.05 kg PO_4^{3-} eq. 66%
Others Average 0.01 kg PO_4^{3-} eq. 21%

Figure 43. Eutrophication indicator results by building size.

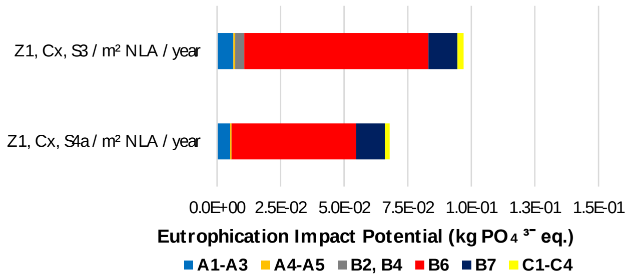
Units per m² NLA/year

Braced frame



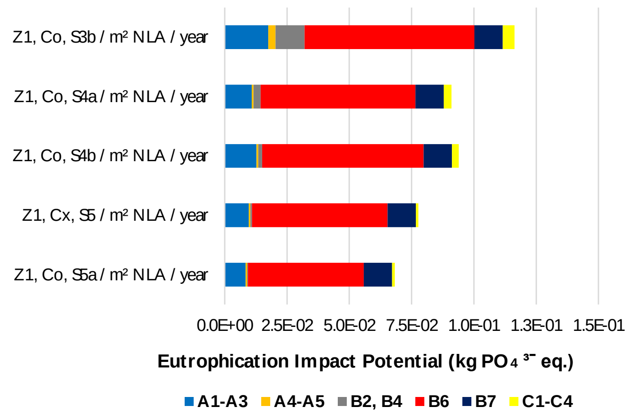
Total Average 0.08 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 12%
B6 Average 0.05 kg PO_4^{3-} eq. 66%
Others Average 0.02 kg 22%

Post Tension



Total Average 0.08 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 7%
B6 Average 0.06 kg PO_4^{3-} eq. 74%
Others Average 0.02 kg PO_4^{3-} eq. 19%

Rigid Frame



Total Average 0.09 kg PO_4^{3-} eq.
A1–A3 Average 0.01 kg PO_4^{3-} eq. 13%
B6 Average 0.06 kg PO_4^{3-} eq. 66%
Others Average 0.02 kg PO_4^{3-} eq. 21%

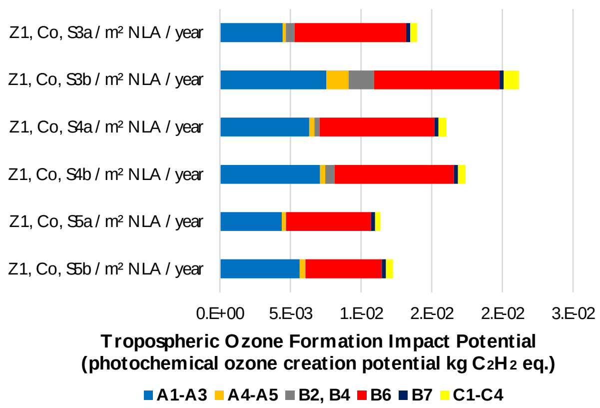
Figure 44. Eutrophication indicator results by structural system.

6.3.3 Area of protection: health and wellbeing/ecosystem (regional scale)

6.3.3.1 Tropospheric ozone formation

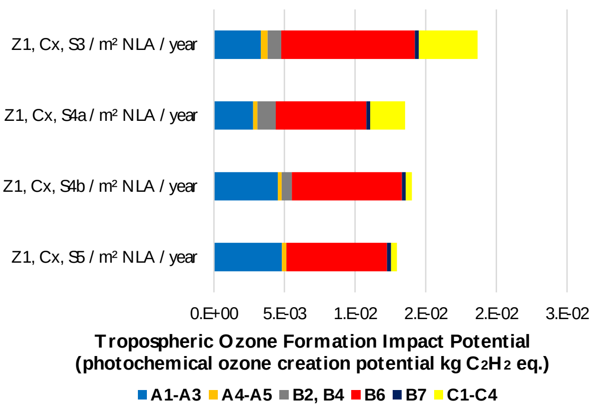
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 15.4E^{-3} kg C_2H_2 eq.
A1–A3 Average 5.9E^{-3} kg C_2H_2 eq. 38%
B6 Average 7.5E^{-3} kg C_2H_2 eq. 49%
Others Average 2.0E^{-3} kg C_2H_2 eq. 13%

Building Activity: Commercial Mixed

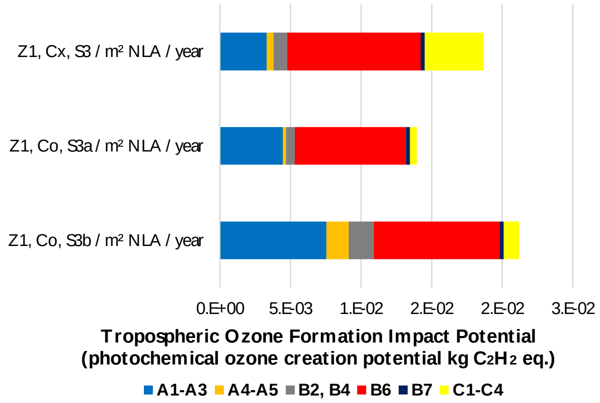


Total Average 14.8E^{-3} kg C_2H_2 eq.
A1–A3 Average 3.9 E^{-3} kg C_2H_2 eq. 26%
B6 Average 7.7 E^{-3} kg C_2H_2 eq. 52%
Others Average 3.2 E^{-3} kg C_2H_2 eq. 22%

Figure 45. Tropospheric ozone formation indicator results by building activity.

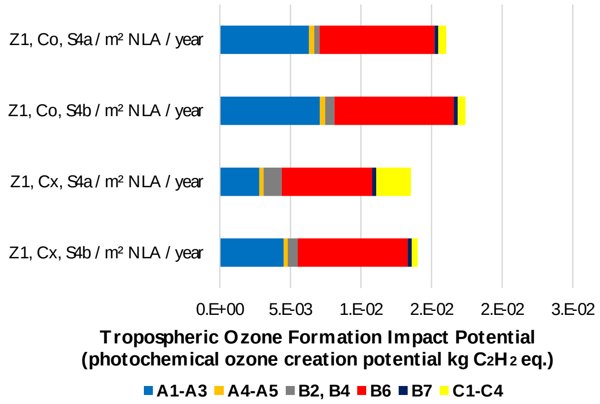
Units per m² NLA/year

Size class 3



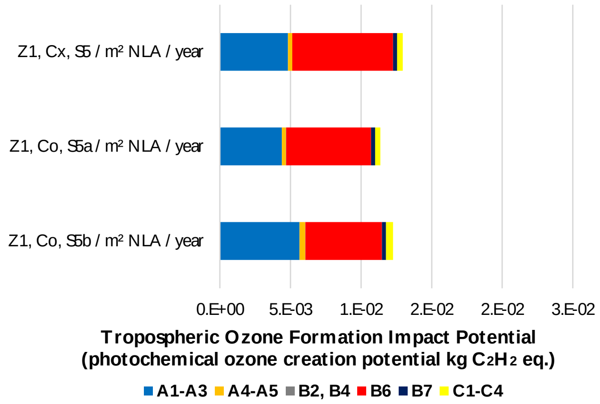
Total Average 17.9 E^{-3} kg C_2H_2 eq.
A1–A3 Average 5.1 E^{-3} kg C_2H_2 eq. 28%
B6 Average 8.8 E^{-3} kg C_2H_2 eq. 49%
Others Average 4.1 E^{-3} kg C_2H_2 eq. 23%

Size class 4



Total Average 15.3 E^{-3} kg C_2H_2 eq.
A1–A3 Average 5.2 E^{-3} kg C_2H_2 eq. 34%
B6 Average 7.7 E^{-3} kg C_2H_2 eq. 50%
Others Average 2.4 E^{-3} kg C_2H_2 eq. 16%

Size class 5

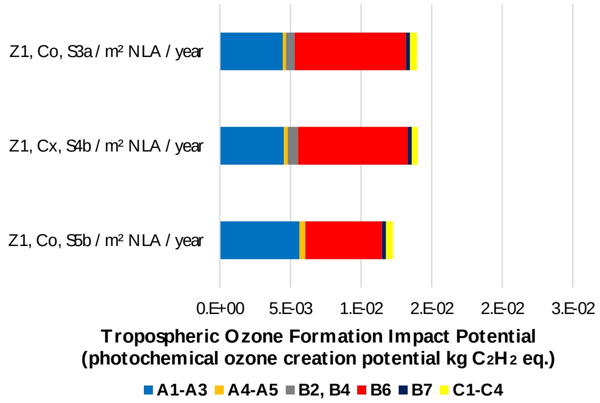


Total Average 12.2 E^{-3} kg C_2H_2 eq.
A1–A3 Average 4.9 E^{-3} kg C_2H_2 eq. 41%
B6 Average 6.2 E^{-3} kg C_2H_2 eq. 51%
Others Average 1.1 E^{-3} kg C_2H_2 eq. 9%

Figure 46. Tropospheric ozone formation indicator results by building size.

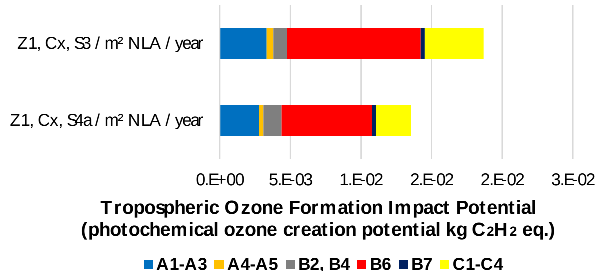
Units per m² NLA/year

Braced frame



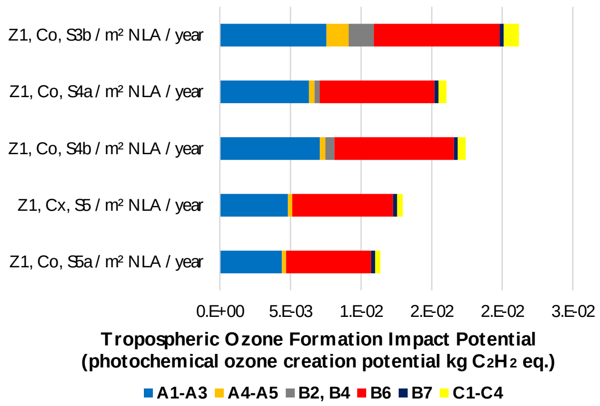
Total Average 13.4 E^{-3} kg C_2H_2 eq.
A1–A3 Average 4.9 E^{-3} kg C_2H_2 eq. 36%
B6 Average 7.0 E^{-3} kg C_2H_2 eq. 52%
Others Average 1.5 E^{-3} kg C_2H_2 eq. 11%

Post Tension



Total Average 16.1 E^{-3} kg C_2H_2 eq.
A1–A3 Average 3.1 E^{-3} kg C_2H_2 eq. 19%
B6 Average 7.9 E^{-3} kg C_2H_2 eq. 49%
Others Average 5.1 E^{-3} kg C_2H_2 eq. 32%

Rigid Frame



Total Average 15.8 E^{-3} kg C_2H_2 eq.
A1–A3 Average 6.0 E^{-3} kg C_2H_2 eq. 38%
B6 Average 7.7 E^{-3} kg C_2H_2 eq. 49%
Others Average 2.0 E^{-3} kg C_2H_2 eq. 13%

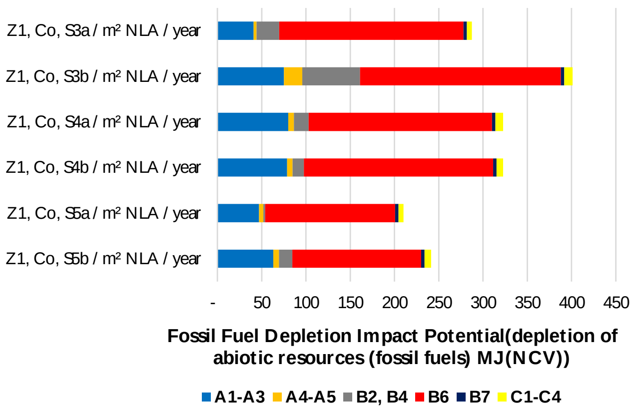
Figure 47. Tropospheric ozone formation indicator results by structural system.

6.3.4 Area of protection: natural resources (global scale)

6.3.4.1 Abiotic resource depletion (fossil fuels)

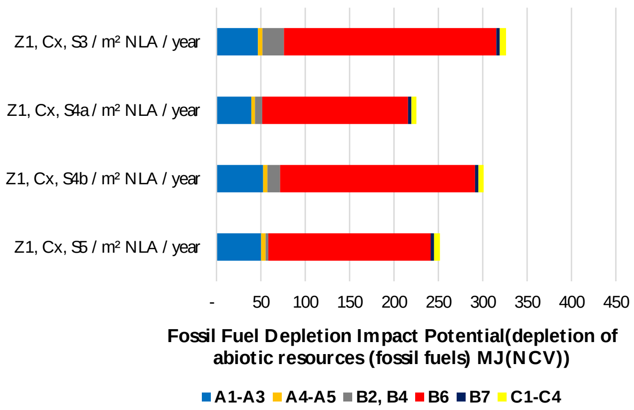
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 297.6 MJ
A1–A3 Average 64.1 MJ 22%
B6 Average 191.4 MJ 64%
Others Average 42.0 MJ 14%

Building Activity: Commercial Mixed

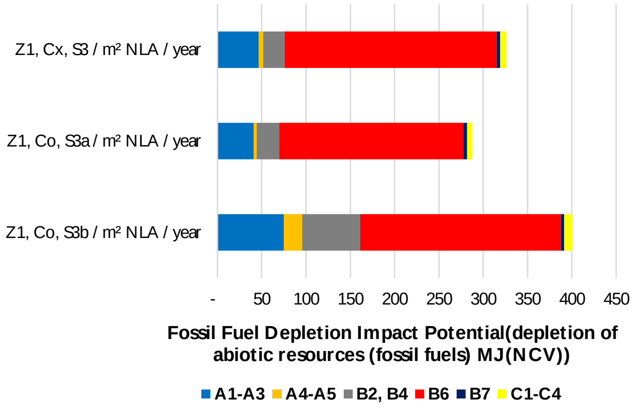


Total Average 276.0 MJ
A1–A3 Average 47.1 MJ 17%
B6 Average 201.5 MJ 73%
Others Average 27.4 MJ 10%

Figure 48. Abiotic resource depletion (fossil fuels) indicator results by building activity.

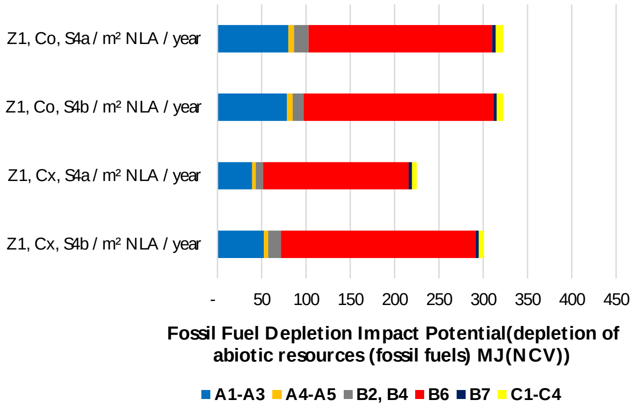
Units per m² NLA/year

Size class 3



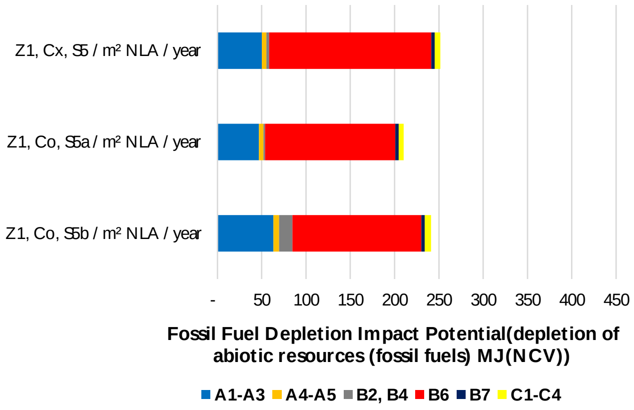
Total Average 338.2 MJ
A1–A3 Average 54.2 MJ 16%
B6 Average 224.7 MJ 66%
Others Average 59.3 MJ 18%

Size class 4



Total Average 292.8 MJ
A1–A3 Average 62.6 MJ 21%
B6 Average 201.2 MJ 69%
Others Average 29.0 MJ 10%

Size class 5

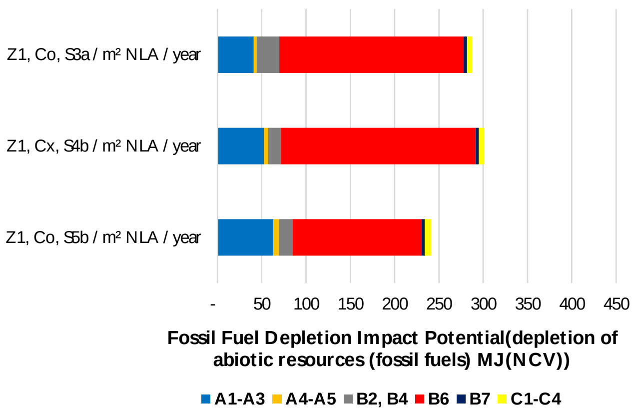


Total Average 234.4 MJ
A1–A3 Average 53.4 MJ 23%
B6 Average 158.5 MJ 68%
Others Average 22.5 MJ 10%

Figure 49. Abiotic resource depletion (fossil fuels) indicator results by building size.

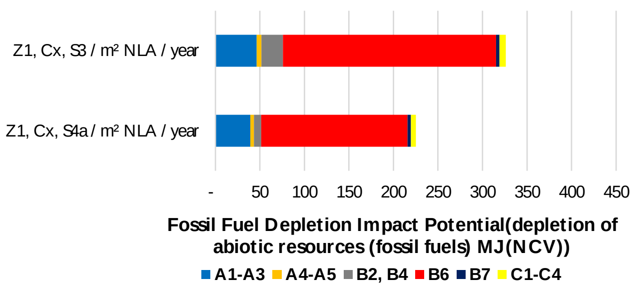
Units per m² NLA/year

Braced frame



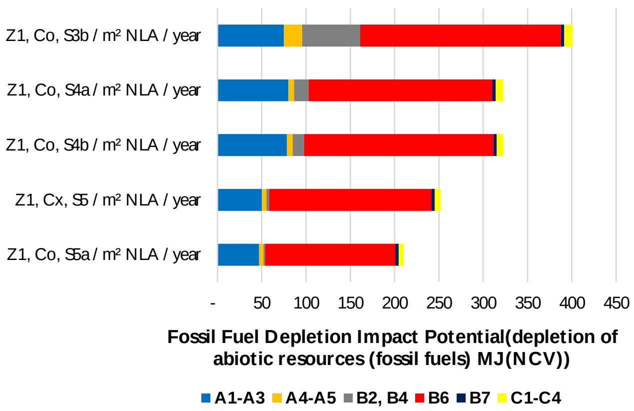
Total Average 276.5 MJ
A1–A3 Average 52.2 MJ 19%
B6 Average 191.1 MJ 69%
Others Average 33.3 MJ 12%

Post Tension



Total Average 275.6 MJ
A1–A3 Average 42.9 MJ 16%
B6 Average 201.8 MJ 73%
Others Average 30.9 MJ 11%

Rigid Frame



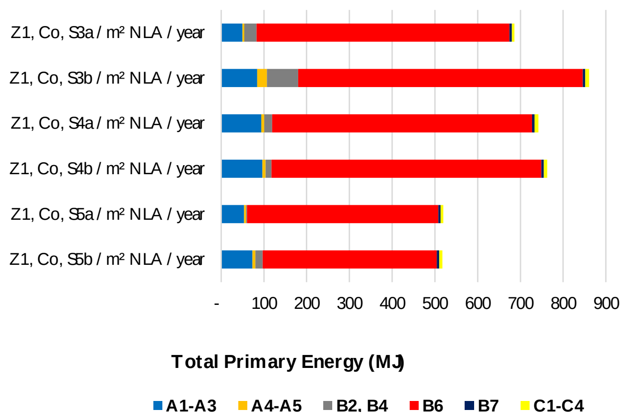
Total Average 301.7 MJ
A1–A3 Average 66.2 MJ 22%
B6 Average 195.5 MJ 65%
Others Average 40.0 MJ 13%

Figure 50. Abiotic resource depletion (fossil fuels) indicator results by structural system.

6.3.4.2 Total primary energy

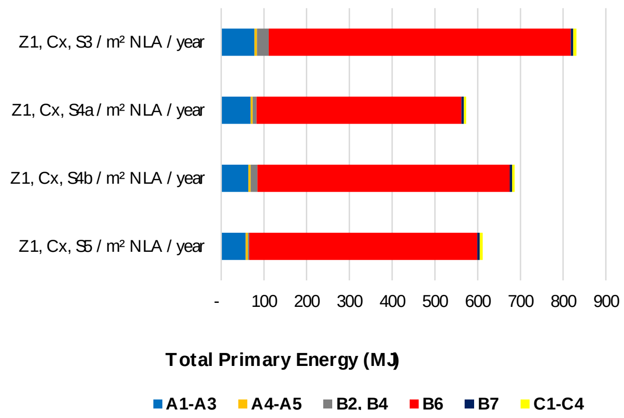
Units per m² NLA/year

Building Activity: Commercial Office



Total Average 681.3 MJ
A1–A3 Average 75.2 MJ 11%
B6 Average 558.5 MJ 82%
Others Average 47.6 MJ 7%

Building Activity: Commercial Mixed

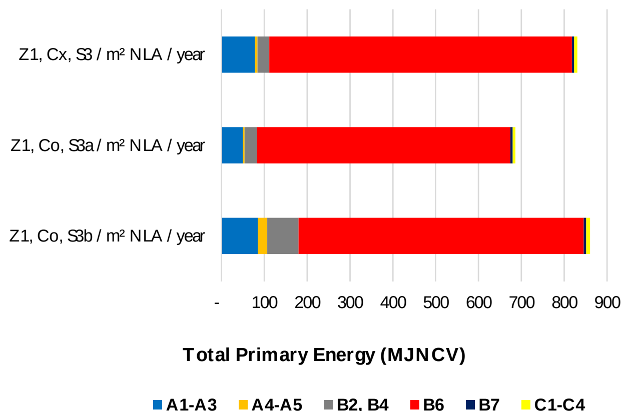


Total Average 675 MJ
A1–A3 Average 66.9 MJ 10%
B6 Average 577.2 MJ 85%
Others Average 31.6 MJ 5%

Figure 51. Total primary energy by building activity.

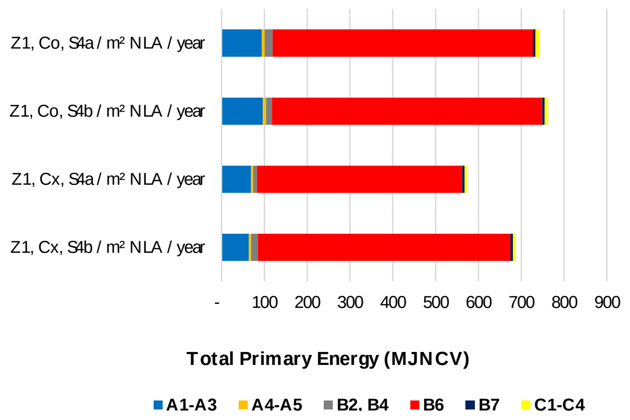
Units per m² NLA/year

Size class 3



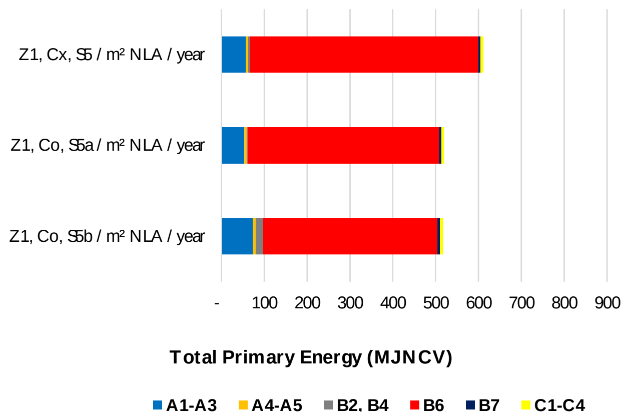
Total Average 792.5 MJ
A1–A3 Average 70.8 MJ 9%
B6 Average 654.6 MJ 83%
Others Average 67.4 MJ 8%

Size class 4



Total Average 691.0 MJ
A1–A3 Average 80.6 MJ 12%
B6 Average 577.1 MJ 84%
Others Average 33.4 MJ 5%

Size class 5

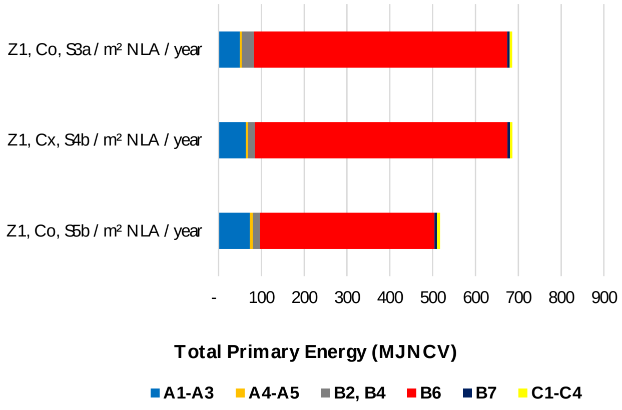


Total Average 549.5 MJ
A1–A3 Average 61.2 MJ 11%
B6 Average 462.5 MJ 84%
Others Average 25.8 MJ 5%

Figure 52. Total primary energy by building size.

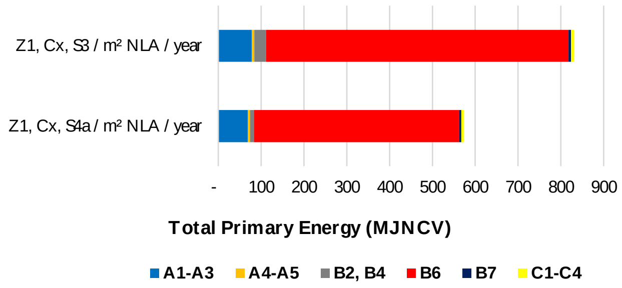
Units per m² NLA/year

Braced frame



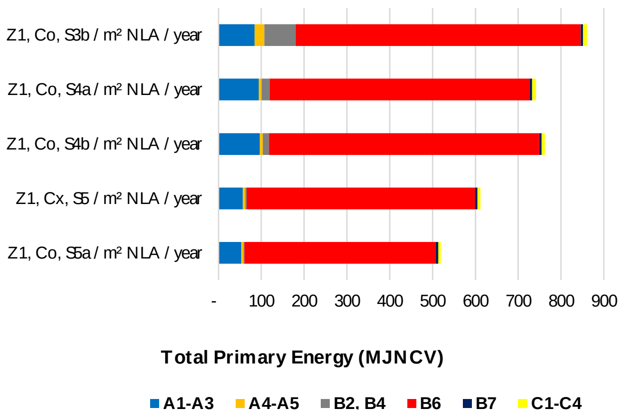
Total Average 630.0 MJ
A1–A3 Average 62.3 MJ 10%
B6 Average 529.6 MJ 84%
Others Average 38.1 MJ 6%

Post Tension



Total Average 702.1 MJ
A1–A3 Average 73.4 MJ 10%
B6 Average 592.8 MJ 84%
Others Average 35.9 MJ 5%

Rigid Frame



Total Average 699.2 MJ
A1–A3 Average 77.0 MJ 11%
B6 Average 577.0 MJ 83%
Others Average 45.2 MJ 6%

Figure 53. Total primary energy by structural system.

References

AIA. (2007). *Integrated project delivery: A guide.* American Institute of Architects (AIA). Retrieved from http://www.aia.org/about/initiatives/AIAS076981

AIA. (2008). *The Architect's Handbook of Professional Practice* (14th ed.). New Jersey, USA: John Wiley & Sons Inc.

Akkon Steel Structure Systems Co. (2012). *Light gauge steel profiles [Declaration No.: EPD-AKK-2012111-E].* Institut Bauen und Umwelt e.V. (IBU).

ALCAS. (2014). *Requirements for the development of AusLCI datasets*.

Alcorn, A. (2010). *Global sustainability and the New Zealand house* (PhD Thesis). Victoria University of Wellington, New Zealand.

Ali, M. M. & Moon, K. S. (2007). Structural developments in tall buildings: current trends and future prospects. *Architectural Science Review*, 50(3), 205–223.

Allied Concrete. (2014). *Ready mixed concrete using Holcim manufactured cement [Declaration No.: S-P-00555].* The International EPD® System.

Alucoil SA. (2015). *Aluminium composite panel for architectural sector, corporate design applications, automotive and naval sector, among others [Declaration No.: S-P-00363]*. The International EPD® System.

American Wood Council and Canadian Wood Council. (2013a). *North American wood I-joists [Declaration No.: 13CA24184.106.1].* UL Environment.

American Wood Council and Canadian Wood Council. (2013b). *North American laminated veneer lumber [Declaration No.: 13CA24184.105.1]*.UL Environment.

Amitrano, L. (Ed.), Isaacs, N., Saville-Smith, K., Donn, M., Camilleri, M., Pollard, A., Babylon, M., Bishop, R., Roberti, J., Burrough, L., Au, P., Bint, L., Jowett, J., Hills, A. & Cory, S. (2014a). *BEES Part 1: Final report*. BRANZ Study Report SR297/1. Judgeford, New Zealand: BRANZ Ltd.

Amitrano, L. (Ed.), Isaacs, N., Saville-Smith, K., Donn, M., Camilleri, M., Pollard, A., Babylon, M., Bishop, R., Roberti, J., Burrough, L., Au, P., Bint, L., Jowett, J., Hills, A. & Cory, S. (2014b). *BEES Part 2: Appendices to final report*. BRANZ Study Report SR297/2. Judgeford, New Zealand: BRANZ Ltd.

ANIQ. (2015). *Expandable polystyrene (EPS) insulation board [Declaration No.: S-P-00695]*. The International EPD® System.

ASHRAE. (2002). ASHRAE Guideline 14-2002*: Measurement of energy and demand savings*. ASHRAE Standards Committee. Retrieved from https://gaia.lbl.gov/people/ryin/public/Ashrae_guideline14-2002_Measurement%20of%20Energy%20and%20Demand%20Saving%20.pdf

Athena Sustainable Materials Institute. (1997). *Demolition energy analysis of office building structural systems*. Ottawa, Canada: Author.

Athena Sustainable Materials Institute. (1999). *Life cycle inventory analyses of building envelope materials – update and expansion*. Ottawa, Canada: Author.

Athena Sustainable Materials Institute. (2013). *A grander view: The Enermodal Engineering Office Building, Kitchener, ON: An environmental building declaration According to EN 15978 standard*. Ottawa, Canada: Author. Retrieved from http://www.athenasmi.org/wp-content/uploads/2013/06/EnermodalEnvironmentalDeclaration.pdf

Athena Sustainable Materials Institute. (2014). *The Lafarge Innovation Hub, Edmonton, AB: An environmental building declaration according to EN 15978 standard*. Technical Report. Ottawa, Canada: Author. Retrieved from http://www.athenasmi.org/wp-content/uploads/2014/08/Lafarge_Hub_Environmental_Declaration_August_2014.pdf

Athena Sustainable Materials Institute. (2015). *Wood Innovation and Design Centre: Prince George, BC: An environmental building declaration according to the EN 15978 standard*. Technical Report. Ottawa, Canada: Author. Retrieved from http://www.athenasmi.org/wp-content/uploads/2015/06/WIDC_Environmental_Declaration_final.pdf

Beattie, G. J. (2007). *Design guide: Slender precast concrete panels with low axial load.* Judgeford, New Zealand: BRANZ Ltd.

Bensouda, N. (2004). *Extending and formalizing the energy signature method for calibrating simulations and illustrating with application for three California climates* (Master's Thesis). Texas A&M University, Texas USA. Retrieved from http://repository.tamu.edu/bitstream/handle/1969.1/1080/etd-tamu-2004B-MEEN-Bensouda-2.pdf?sequence=1

Berg, B. (2014). *Using BIM to calculate accurate material quantities for early design phase life cycle assessment* (Master's Thesis). Victoria University of Wellington, New Zealand.

BIMForum. (2013). *Level of development specification for building information models*.

Bint, L. (2012). *Water performance benchmarks for New Zealand: Understanding water consumption in commercial office buildings* (PhD Thesis). Victoria University of Wellington, New Zealand.

Bluescope. (2015). *Steel – welded beams and columns [Declaration No.: S-P-00559]*. The Australasian EPD® Programme.

BS Holz (Studiengemeinschaft Holzleimbau e.V.). (2013a). *Cross laminated timber (X-Lam) [Declaration No.: EPD-SHL-2012211-EN]*. Institut Bauen und Umwelt e.V. (IBU).

BS Holz (Studiengemeinschaft Holzleimbau e.V.). (2013b). *Glued laminated timber [Declaration No.: EPD-SHL-2012017-EN]*; Institut Bauen und Umwelt e.V. (IBU).

BTC. (2015). *Environmental Product Declaration – Flexible sheets for waterproofing – BTC system [Declaration No.: S-P-00694]*. The International EPD® System.

BWA (Bitumen Waterproofing Association). (2013). *Environmental declaration for bitumen roof waterproofing systems*.

CAENZ. (2008). *New Zealand energy information handbook* (3rd ed.). Christchurch, New Zealand: New Zealand Centre for Advanced Engineering.

Cement & Concrete Association of New Zealand. (2010). *New Zealand guide to concrete construction*. Wellington, New Zealand: Author.

Cement & Concrete Association of New Zealand. (2011). *Best practice guide for the use of recycled aggregates in new concrete (TR14).* Wellington, New Zealand: Author.

CEN. (2011). EN 15978: *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*.

CEN. (2013). EN 15804 (2012 + A1): *Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products*.

CIBSE. (1998). *CIBSE AM11 Building Energy and Environmental Modelling (CIBSE Applications Manual 11)*. London, UK: Chartered Institution of Building Services Engineers (CIBSE).

CIBSE. (2006). *CIBSE guide A: Environmental design* (7th ed.). London, UK: Chartered Institution of Building Services Engineers (CIBSE).

Coelho, C. (2011). *New Zealand's electricity generation dataset: A life cycle inventory for carbon footprints*.

Cory, S. & Amitrano, L. (2014). Changing models. *Build*, 145, 56–57.

Cory, S., Gates, A. & Donn, M. (2011). *The creation of generic energy simulation models which represent typical commercial buildings and their calibration against real energy data*. 12th Conference of International Building Performance Simulation Association. Sydney Australia: International Building Performance Simulation Association (IBPSA).

CSIRO. (2009). *Life cycle inventory of Australian forestry and wood products.* Prepared on behalf of Forest and Wood Products Australia.

Curtis, M. D. (2015). *Physical characteristics of new non-residential buildings 2014*. BRANZ Study Report SR331. Judgeford, New Zealand: BRANZ Ltd.

Danosa. (2015). *Environmental product declaration of Danopol PVC waterproofing sheet [Declaration No.: S-P-00691 v 1.0]*. The International EPD® System.

Donn, M. & Garde, F. (2014). *Solution sets and net zero energy buildings: A review of 30 net ZEBs case studies worldwide*. Technical Report No. Subtask C – DC.TR1. Reunion Island: University of Reunion Island, ESIROI/PIMENT.

Donn, M., Selkowitz, S. & Bordass, B. (2012). The building performance sketch. *Building Research & Information*, 40(2), 186–208. http://doi.org/10.1080/09613218.2012.655070

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

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., 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.

Emmitt, S. (2007). *Design management for architects*. Oxford, UK: Blackwell Publishing Ltd.

Energy Market Authority. (2015). *Singapore energy statistics 2015*.

Eternit-Werke Ludwig Hatschek AG. (2013). *AURiA large size fibre cement panels [Declaration No.: EPD-ELH-2013321-D]*. Institut Bauen und Umwelt e.V. (IBU).

European Association for Panels and Profiles. (2013). *Profiled sheets made of steel for roof, wall and deck constructions [Declaration No.: EPD-EPQ-20130236-CBE1-EN]*. Institut Bauen und Umwelt e.V. (IBU).

Europrofil AB. (2014). *Light gauge steel profile [Declaration No.: S-P-00537].* The International EPD® System.

EXIBA (European Extruded Polystyrene Insulation Board Association). (2014). *Extruded polystyrene (XPS) foam insulation with HBCD flame retardant [Declaration No.: EPD-EXI-20140154-IBE1-EN]*. Institut Bauen und Umwelt e.V. (IBU).

Fernandez, N. P. (2008). *The influence of construction materials on life-cycle energy use and carbon dioxide emissions of medium size commercial buildings* (Master's Thesis). Victoria University of Wellington, New Zealand.

Forest and Wood Products Australia Ltd. (2015a). *Environmental Product Declaration: Plywood [EPD Registration No.: S-P-00564]*. The Australasian EPD® Programme.

Forest and Wood Products Australia Ltd. (2015b).*Environmental Product Declaration: Softwood timber [EPD Registration No.: S-P-00560]*. The Australasian EPD® Programme.

Forman Building Systems/Dow Deutschland GmbH & Co. (2013). *XENERGY™ XPS extruded polystyrene foam insulation [Declaration No.: EPD-DOW-2013111-E].* Institut Bauen und Umwelt e.V. (IBU).

Fraunhofer Institute for Solar Energy Systems (2016). *Photovoltaics report*. https://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

Freudenberg. (2015). *ECOZERO® panels made of recycled polyester for thermal and acoustic insulation of buildings [Declaration No.: S-P-00218]*. The International EPD® System.

Gates, A. (2013). *Determining the modelling input parameters for heating, ventilation, and air conditioning systems in New Zealand commercial buildings* (Master's Thesis). Victoria University of Wellington, New Zealand.

GDA (German Aluminium Association). (2013a). *Blank aluminium sheet [Declaration No.: EPD-GDA-20130258-IBG1-EN]*. Institut Bauen und Umwelt e.V. (IBU).

GDA (German Aluminium Association). (2013b). *Cold formed aluminium sheet for exterior applications [Declaration No.: EPD-GDA-20130260-IBG1-EN].* Institut Bauen und Umwelt e.V. (IBU).

Gunel, M. H. & Ilgin, H. E. (2007). A proposal for the classification of structural systems of tall buildings. *Building and Environment*, 42(7), 2667–2675. http://doi.org/10.1016/j.buildenv.2006.07.007

Hammond, G. & Jones, C. (2011). *Inventory of carbon & energy (ICE) – version 2.* Bath, UK: University of Bath.

Heijungs, R. & Huijbregts, M. A. (2004). A review of approaches to treat uncertainty in LCA. In *iEMSs 2004 International Congress Complexity and Integrated Resources Management*. Osnabrueck, Germany. Retrieved from http://www.iemss.org/iemss2004/pdf/lca/heijarev.pdf

Holm, L., Schaufelberger, J. E., Griffin, D. & Cole, T. (2005). Construction cost estimating process and practices. Upper Saddle River, NJ: Pearson Education.

Hopfe, C. J. & Hensen, J. L. M. (2011). Uncertainty analysis in building performance simulation for design support. *Energy and Buildings*, 43(10), 2798–2805. http://doi.org/10.1016/j.enbuild.2011.06.034

Hume Cemboard Industries Sdn Bhd. (2014). *PRIMA fibre cement board [Declaration No.: EPD-HUM-20130186-IAD1-EN]*. Institut Bauen und Umwelt e.V. (IBU).

Ibn-Mohammed, T., Greenough, R., Taylor, S., Ozawa-Meida, L. & Acquaye, A. (2013). Operational vs. embodied emissions in buildings – a review of current trends. *Energy and Buildings*, 66, 232–245. http://doi.org/10.1016/j.enbuild.2013.07.026

IEA. (2004). *International Energy Agency: Annex 31 Energy-related environmental impact of buildings: Decision-making framework*. Canada: Canada Mortgage and Housing Corporation.

IFBS. (2013). *Profiled sheets made of steel for roof, wall and deck constructions [Declaration No.: EPD-IFBS-2013211-EN].* Institut Bauen und Umwelt e.V. (IBU).

IPCC (2012). *Renewable energy sources and climate change mitigation – summary for policymakers and technical summary*. http://www.ipcc.ch/report/srren/

Iqbal, A. (2015). *Cross-laminated timber for building structures*. BRANZ Study Report SR336. Judgeford, New Zealand: BRANZ Ltd.

Isaacs, N. & Hills, A. (2013). Understanding the New Zealand non-domestic building stock. *Building Research & Information*, 42(1), 95–108. http://doi.org/10.1080/09613218.2013.831274

Isaacs, N. (Ed.), Saville-Smith, K., Bishop, R., Camilleri, M., Jowett, J., Hills, A., Moore, D., Babylon, M., Donn, M., Heinrich, M. & Roberti, H. (2009). *Building Energy*

End-Use Study (BEES) Years 1 & 2. BRANZ Study Report SR224. Judgeford, New Zealand: BRANZ Ltd.

ISO. (2006). ISO 14040: *Environmental management – Life cycle assessment – Principles and framework*.

ISO. (2010). ISO 14025: *Environmental labels and declarations – Type III environmental declarations – Principles and procedures*

Isover Saint-Gobain. (2015a). *Fieltro Liviano HR (glass wool insulation) [Declaration No.: S-P-00730].* The International EPD® System.

Isover Saint-Gobain. (2015b) *Acustiver R 400 (glass wool insulation) [Declaration No.: S-P-00728]*. The International EPD® System.

Isover Saint-Gobain. (2015c). *Acustiver P sin velo (glass wool insulation) [Declaration No.: S-P-00727].* The International EPD® System.

Jackon Insulation GmbH. (2015). *JACKODUR Plus – Extruded polystyrene (XPS) with HFO 1234ze and alternative flame retardant [Declaration No.: EPD-JAI-20150249-IBC1-EN]*. Institut Bauen und Umwelt e.V. (IBU).

Jaques, R. (2002). *Environmental impacts associated with New Zealand structural steel manufacture – preliminary study.* BRANZ Study Report SR113. Judgeford, New Zealand: BRANZ Ltd.

Keene, S. & Smythe, C. (2009). *End-of-life options for construction and demolition timber waste: A Christchurch case study*. ENNR429: Final Year Project. Submitted 5/10/2009 to the University Of Canterbury's Natural Resources and Civil Department. Christchurch: University of Canterbury.

Kim, D. (2010). Optimizing cost effective energy conservation measures for building envelope. Energy Engineering, 107(3), 70–80.

Knauf Insulation, d.o.o., Skofja Loka. (2014). *DP-5 multipurpose rock mineral wool insulation [Declaration No.: EPD-KNA-20140053-CBC1-EN].* Institut Bauen und Umwelt e.V. (IBU).

Lemay, L. (2011). *Life cycle assessment of concrete buildings.* Concrete Sustainability Report CSR04. Silver Spring, MD: National Ready Mixed Concrete Association.

Löhnert, G., Dalkowski, A. & Sutter, W. (2003). *Integrated design process: A guideline for sustainable and solar-optimised building design*. Design Guide. Berlin/Zug: International Energy Agency.

Love, S. (2010). *Carbon footprint of New Zealand laminated veneer lumber*. Rotorua, New Zealand: Scion.

Marley Eternit Ltd & Tegral Building Products Ltd. (2015). *Coated fibre cement slates [Declaration No.: EPD-MAR-20140216-CCD1-EN].* Institut Bauen und Umwelt e.V. (IBU).

MBIE. (2013). *Energy in New Zealand 2013–2012 calendar year edition*. Wellington, New Zealand: Ministry of Business, Innovation and Employment.

MBIE. (2014). *Energy in New Zealand 2014–2013 calendar year edition*. Wellington, New Zealand: Ministry of Business, Innovation and Employment.

MBIE. (2015). *Energy in New Zealand 2015–2014 calendar year edition*. Wellington, New Zealand: Ministry of Business, Innovation and Employment.

Menezes, A. C. K. de, Cripps, A., Bouchlaghem, D. & Buswell, R. A. (2011). *Predicted vs. actual energy performance of non-domestic buildings*. ICAE 2011 – International Conference on Applied Energy, Perugia, Italy.

MfE. (2010). *A guide to landfill methane in the New Zealand Emissions Trading Scheme*. Wellington: Ministry for the Environment.

MfE. (2015). *Guidance for voluntary corporate greenhouse gas reporting – 2015: Using data and methods from the 2013 calendar year.* Wellington: Ministry for the Environment.

Moore, A. *Life cycle assessment (LCA) of a solar photovoltaic system installed in Australia and New Zealand.* Retrieved from http://www.lcanz.org.nz/sites/default/files/lca_decision_support_4_moore_a.pdf.

Nebel, B., Alcorn, A. & Wittstock, B. (2011). *Life cycle assessment: Adopting and adapting overseas LCA data and methodologies for building materials in New Zealand*. Wellington, New Zealand: Ministry of Agriculture and Forestry.

New Zealand Concrete Masonry Association Inc and Cement & Concrete Association of New Zealand. (2012). *New Zealand concrete masonry manual – 4.1: Design of reinforced concrete masonry structures*. Retrieved from http://www.nzcma.org.nz/document/279-27/14.NZCMA_MM_-_4.1_-_Design_of_Reinforced_Concrete_Masonry_Structures.pdf.

New Zealand Construction Institute Council (NZCIC). (2004). *New Zealand Construction Institute Council (NZCIC) design documentation guidelines.* New Zealand Construction Institute Council (NZCIC). Retrieved from http://www.nzcic.co.nz/

New Zealand Ministry of Economic Development. (2009). *Assessment of the future costs and performance of solar photovoltaic technologies in New Zealand.* Wellington, New Zealand: Author.

Newcombe, M. P. (2011). *Seismic design of post-tensioned timber frame and wall buildings* (PhD Thesis). University of Canterbury, Canterbury, New Zealand. Retrieved from http://ir.canterbury.ac.nz/handle/10092/6399

NZIQS. (2012). *Elemental analysis of costs of building projects*. Wellington, New Zealand: New Zealand Institute of Quantity Surveyors.

Ostime, N. (2013). *RIBA job book* (9th ed.). London, UK: RIBA Publishing.

PE International. (2010); *Summary report - Life cycle assessment of float glass.* Report for Glass for Europe.

PwC. (2014). *Critical review of the steel co-product allocation method developed by EUROFER in cooperation with the World Steel Association*.

Rolan Aislantes Minerales SA de CV. (2014). *Rolan rockwool insulation board [Declaration No.: S-P-00532].* The International EPD® System.

Sacayon Madrigal, E. E. (2016) *Assessment of the life cycle-based environmental impacts of New Zealand electricity* (Master's Thesis). Massey University.

Samphaongoen, P. (2010). *A visual approach to construction cost estimating* (Master's Thesis). Marquette University, Wisconsin, US.

Smith, J. & Jaggar, D. M. (2006). *Building cost planning for the design team*. Routledge.

Standards New Zealand. (2004). *Design of reinforced concrete masonry structures* (NZS 4230).

Standards New Zealand. (2007*). Energy efficiency – Large buildings – Building thermal envelope* (NZS 4243.1).

Standards New Zealand. (2011). *Timber-framed buildings* (NZS 3604).

Tonkin & Taylor. (2010). *Recommendations for methodologies for ETS landfill gas emission reporting.*.

Treloar, G. J., Fay, R., Ilozor, B. & Love, P. E. D. (2001). An analysis of the embodied energy of office buildings by height. *Facilities*, 19(5/6), 204–214.

Turk Ytong Sanayi A.S. (2015). *Ytong® autoclaved aerated concrete [Declaration No.: EPD-YTO-20150044-IAD1-EN].* Institut Bauen und Umwelt e.V. (IBU).

UAC Berhad. (2013). *UAC fibre cement board [Declaration No.: EPD-UAC-20130008-IAC1-EN].* Institut Bauen und Umwelt e.V. (IBU).

US DOE. (2008). *M&V Guidelines: Measurement and Verification for Federal Energy Projects Version 3.0*. US Department of Energy Federal Energy Management Program. Retrieved from http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf

Wang, W., Padgett, J., De La Cruz, F. & Barlaz, M. (2011). Wood biodegradation in laboratory-scale landfills. *Environmental Science & Technology,* 45(16), 6864–6871.

Wilburn, D. R. & Goonan, T. G. (1998). *Aggregates from natural and recycled sources: Economic assessments for construction applications – A materials flow analysis.* US Geological Survey Circular 1176.

World Aluminium. (2013). *Global life cycle inventory data for the primary aluminium industry – 2010 data.*.

worldsteel. (2014) *A methodology to determine the LCI of steel industry co-products*.

Xella Baustoffe GmbH. (2012). *Ytong® autoclaved aerated concrete (AAC) [Declaration No.: EPD-XEL-20120006-IAD1-EN].* Institut Bauen und Umwelt e.V. (IBU).

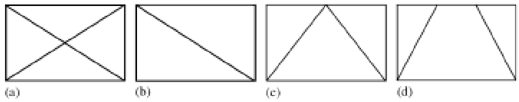
Ximenes, F., Brooks, P., Wilson, C. and Giles, D. (2013). *Carbon storage in engineered wood products in landfills*. Melbourne, Australia: Forest and Wood Products

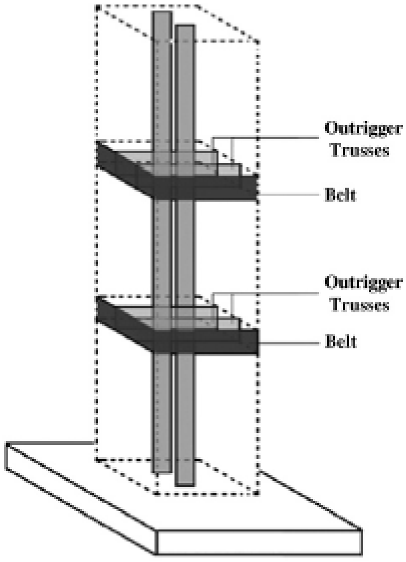
Australia. Retrieved from http://www.fwpa.com.au/rd-and-e/processing/181-carbon-storage-in-engineered-wood-products-in-landfills.html

Yung, P., Lam, K. C. & Yu, C. (2013). An audit of life cycle energy analyses of buildings. *Habitat International*, 39, 43–54. http://doi.org/10.1016/j.habitatint.2012.10.003

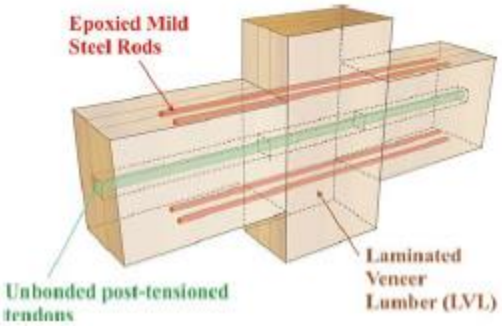
Appendix A: Classification of structural systems

Structural systems comprising steel, reinforced concrete or both (Gunel & Ilgin, 2007)

System	Material	Description
Rigid frame (moment framing)	Steel and reinforced concrete	Based on the fact that column to beam connections have enough rigidity to hold the nearly unchanged original angles. It is ideally suited to reinforced concrete, whereas in steel, the joints must be modified to increase the stiffness to maintain rigidity in the joints. Rigid frames are more ductile and less vulnerable to severe earthquakes when compared to steel-braced or shear-walled structures. The strength and stiffness are proportional to the dimension of the beam and column dimensions and inversely proportional to column spacing. Columns are placed at spacing to be of least disruption to the floor plan but at a close enough spacing to allow for minimum floor depth. Therefore, in order to obtain an efficient frame design, closely spaced columns and deep beams at the building exterior must be used. 
Braced frames and shear-walled frame systems	Braced frame system: steel Shear-walled frame: reinforced concrete and composite (combination of steel and reinforced concrete)	These systems are in addition to a rigid frame structure. They provide additional stiffness typically in the building's centre/core to increase the resistance to lateral loads. Braced frames improve the lateral resistance to horizontal loads of rigid frames by using additional bracing (compared to rigid frames) to almost eliminate the bending of columns and girders. Braced frames behave like a vertical truss to resist horizontal loading. The braced frame types are typically X, diagonal, K and knee and are usually located around elevators, stairs and service shafts where the diagonal members can be enclosed within permanent walls. Shear walls may be described as vertical cantilevered beams that resist lateral loads that are transmitted to them by the floor diaphragms. Shear walls are typically made from reinforced concrete but more commonly from engineered timber.
Outrigger systems	Steel and composite (combination of steel and reinforced concrete)	Outrigger systems are a modified form of braced frame and shear-walled frame systems. They incorporate rigid frames on the perimeter in which the columns are connected to the central core comprising of either a braced frame or shear-wall system by horizontal outrigger trusses or girders. Furthermore, in most cases, the rigid frame's perimeter columns are interconnected by exterior belt girders so that the building's core cannot rotate under horizontal loading. These outriggers and belt girders extend 1–2 storeys in height.

		
Framed-tube systems	Steel, reinforced concrete and composite construction	The framed-tube system consists of closely spaced perimeter columns interconnected by deep spandrel beams that resembles a tube. This forms one structural system so that the whole building acts as a vertical cantilever to resist overturning moments, and lateral resistance is provided with or without interior columns. The gravity loading is shared between the tube structure and interior columns or walls (if any). The characteristics of this structure are closely spaced perimeter columns and therefore a small window to wall ratio and large open-plan floor plates predominantly free of core bracing and heavy columns. Framed-tube systems come in three sub groups; • Systems without interior columns, shear walls or steel bracings. • Systems with interior columns, shear walls or steel bracings. • Tube-in-tube system, i.e. the perimeter tube is supplemented by an interior tube in the building's core to resist lateral sway.
Braced-tube systems	Steel, reinforced concrete and composite construction	A braced-tube system, also known as a trussed tube or exterior diagonal-tube system, is a framed-tube system with multi-storey diagonal bracing added to the face of the perimeter tube connected to the corner columns of the tube structure.
Bundled-tube systems	Steel, reinforced concrete and composite construction	When the width of a building plan area increases, the effectiveness of the tube system decreases. A bundled-tube system overcomes this issue by using multiple or a cluster of individual tubes interconnected with common interior panels. This system allows any of the individual tubes to be terminated at any height. This makes it possible to design a building with façade setbacks, different shapes and sizes and asymmetrical shapes.

Examples of increasingly used timber-based structural systems in New Zealand (Iqbal, 2015; Newcombe, 2011)

System	Material	Description
Post-tensioned timber frame[15]	Engineered timber LVL, glulam, and CLT	A post-tensioned timber system is a method of joining solid timber elements, i.e. columns, beams or walls such as CLT, by unbonded post-tensioning tendons. Sometimes, mild steel reinforcement in the form of internal epoxied rods or externally mounted and replaceable devices is added to the connections (Newcombe, 2011). As a system, the interfaces between frame connections are able to 'rock' open and closed as the frame sways in an earthquake before springing back into their original position.[16] This rocking effect also allows the building structure to absorb lateral seismic forces and reduce building damage. This is a new generation of seismic engineering known as damage avoidance design. 
Cross-laminated timber (CLT)	Engineered timber	CLT are solid timber panels made of layers of solid timber, alternating grain direction at 90 degrees (whereas glue-laminated timber is layered with the grain), with the exterior layers' grains running lengthways for optimum strength. It is primarily used for roof and floor diaphragms as well as for shear walls (Iqbal, 2015).

[15] www.nzwood.co.nz/learning-centre/timber-structural-systems-post-tensioned-structural-components/
[16] www.nzwood.co.nz/timber-design-awards/college-of-creative-arts-massey-university/

Appendix B: The building performance sketch

LCA is a complex, data-intensive tool, which makes it difficult to apply during early design when there is less data available. Therefore, it is often used later in the design process when fundamental decisions have already been made.

There is increasing recognition of the need for earlier and integrated use of LCA in building design when the benefits are greatest. The relationship of reduced ability to produce a material effect or change with time during the design process is known as the MacLeamy concept or integrated design processes (American Institute of Architects (AIA), 2007), illustrated in Figure 54.

Figure 54 shows that the ability of a building designer to make design decisions is highest and the cost of implementing these decisions is at its lowest during the early phases of the design process. This relationship reverses as the project design progresses throughout the design process to the point where design decisions about building performance are mostly poor performance mitigation or fine tuning/optimisation of an already fully designed building (Donn et al., 2012; AIA, 2007; Emmitt, 2007; International Energy Agency, 2004; Löhnert et al., 2003).

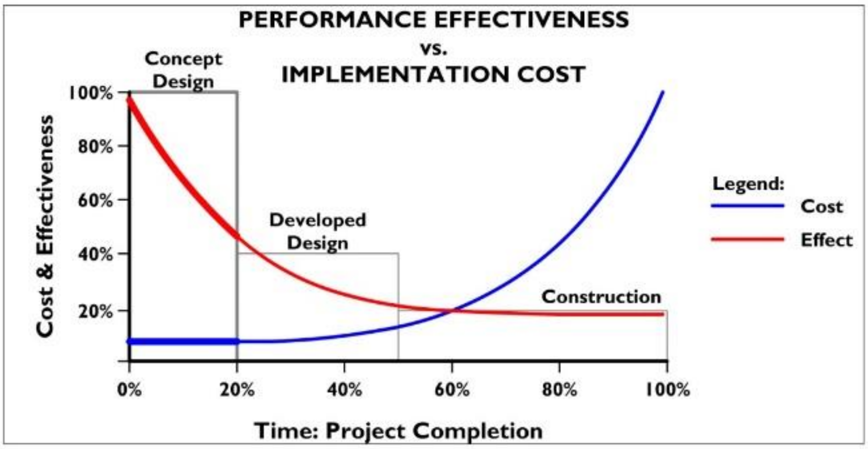


Figure 54. The MacLeamy concept (from AIA, 2007; Donn et al., 2012; Löhnert et al., 2003).

The building performance sketch (BPS) developed by Donn et al. (2012) is a concept or philosophy of design decision making through simulation that enables the MacLeamy concept to be integrated into building simulation. The BPS prescribes that simulation tools be used to examine different design options quickly to facilitate early design decision making. It advocates constructing a BPS model that is detailed enough to produce simulation results of one area of building performance that are accurate enough for decision making specific to the current (at the time of investigation) design process phase and no more. The result is decreased modelling time, effort and therefore cost, while achieving predetermined simulation accuracy requirements.

A BPS of early design information may differ depending on the type of simulation being conducted (for example, operational energy, lighting, environmental impact of materials and so on). The factors affecting how detailed the simulation must be are driven by the design decisions that need to be made and consequently how accurate the results must be to make these decisions.

Table 16 shows a number of different building design frameworks. These frameworks suggest what design decisions to consider and when those decisions should be made in order to deliver a successful building (Löhnert et al., 2003). From this, concept/sketch design typically comprises iteration towards design decisions concerning passive design solutions, building structural design and building thermal envelope design.

Table 16. Phases of design according to different building design frameworks.

Traditional building design process frameworks		**Integrated design process (IDP)/early design building design frameworks**	
NZ Construction Industry Council (NZCIC, 2004)	American Institute of Architects (AIA, 2007)	RIBA Plan of Work (Ostime, 2013)	AIA Integrated Project Delivery (AIA, 2007)
Brief: Defining client and project design problems and requirements as project performance goals.			
-	-	Strategic definition	Conceptualisation
Concept/sketch design: The development and testing of different building design iterations comprising of different building solutions for solving design problems and achieving project performance goals. Design concepts are developed into firm schemes where the relationship and size of spaces and facilities is defined but limited to only key building elements. At the conclusion of this phase, a concept design is selected.			
Concept design	Schematic design	Preparation and brief	Criteria design
Preliminary design		Concept design	
Developed design: The selected concept design is developed so each component, not just key elements, is clearly defined. Typically, sketch details are produced.			
Developed design	Design development	Developed design	Detailed design
Detailed design: Building documentation such as plans and specifications are produced for all building elements to a level that they are directly able to be 'built' from. Design variations to anything but detail at this phase are very disruptive and expensive and often result in further problems, as the project has become very complex and it is hard to identify all the ramifications of changes. Detailed design is the phase most commonly used to obtain a tender for the construction of the works.			
Detailed design	Construction documents	Technical design	Implementation documents
Construction: The detailed design documents are updated with changes that may occur during the tender and contract process and 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. Shop drawings are produced during this stage.			
Construction design	Agency permit Bidding or negotiation Construction	Construction	Agency coordination Final buyout Construction
Handover:			
-	Closeout	Handover	Closeout

Appendix C: Quality assessment in building performance simulation

Quality assessment of BPS models can be considered in terms of simulation accuracy and simulation precision:

- Simulation accuracy is defined as 'how close' calculated results (values) are to their 'true value' measured in reality (ASHRAE, 2002). This difference between simulated results and true values is caused by simulation uncertainties (including errors). This makes simulation accuracy a measure of the cumulative effects of all the simulation errors. Simulation uncertainty relates to a lack of knowledge surrounding the simulation data inputs. Uncertainties occur when no data or information is available, or if it is available, it is wrong or ambiguous (Heijungs & Huijbregts, 2004). This lack of knowledge means there is an increased risk of simulation errors causing simulation inaccuracies.
- Simulation precision is an expression of the closeness of agreement among repeated measurements of the same physical quantity (ASHRAE, 2002). It accounts for offsetting or cancellation errors that occur when a model is over or under-simulating results. These are errors that are not identified by accuracy assessment, making simulation precision an important complement to simulation accuracy assessment.

Simulation accuracy assessment is the process of comparing simulation results to a true value result or figure using a set of criteria that define the maximum acceptable tolerances that express how close (or accurate) is close enough. The result of this simulation accuracy assessment is the measurement of the margin of error in the simulation. This margin of error is the cumulative effect of all the simulation inaccuracies caused by simulation uncertainties and errors.

Simulation calibration is a comprehensive form of accuracy assessment used in building design for operational energy simulation. It is a method of assessing and ensuring operational energy simulations meet predefined accuracy requirements called maximum acceptable calibration tolerances. Critically, it extends beyond determining the deviation of simulation results compared to their true value to include specifying how far this margin of error can be while still facilitating informed decision making (ASHRAE, 2002). This makes calibration a comprehensive best-practice method of accuracy assessment for determining simulation accuracy in building performance.

Simulation calibration is divided into two stages: pre-simulation and post-simulation. Pre-simulation calibration is the processes of assembling the building information and data required to conduct a simulation. The critical aspect of this stage is removing or reducing simulation uncertainties and errors before they are made. Current best-practice quality assurance methods and tools for achieving this are set out in CIBSE AM11 Building Energy and Environmental Modelling (CIBSE Applications Manual 11) (CIBSE, 1998) and CIBSE Guide A: Environmental Design (CIBSE, 2006). Often as-built information or real building data is stipulated as a requirement for modelling assumptions to ensure the model represents real performance as closely as possible.

Post-simulation calibration involves comparing the simulated results to the actual building performance measurements (i.e. constitute the truth model). Following this, adjustments are made to the model to meet the established maximum acceptable calibration tolerances. Once met, the model can be declared as calibrated.

The most important component of the post-calibration methodology is the definition of the maximum acceptable calibration tolerances. Table 17 provides values for two maximum acceptable calibration tolerances metrics defined by ASHRAE Guideline 14:2002 for operational energy use. These are mean bias error (MBE) and the coefficient of variation of root-mean squared error (CV(RMSE)).

Table 17. Acceptable calibration tolerances for operational energy use (ASHRAE, 2002; US DOE, 2008).

Calibration type	Calibration metric	Acceptable calibration tolerance
Monthly	MBEmonth	±5%
	CV(RMSEmonth)	+15%
Hourly	MBEmonth	±10%
	CV(RMSEmonth)	+30%

MBE calculates how accurate the simulated results are predicted to be compared to the measured data truth model (US DOE, 2008). Positive values indicate that the model over-predicts actual values, while negative values indicate that the model under-predicts actual values. However, this MBE assessment is affected by simulation cancellation errors. Simulation cancellation errors occur when the positive and negative differences between simulation and truth model values combine to reduce the MBE. This can provide an incorrect assessment of simulation accuracy, leading to the building designer wrongfully believing that simulated results are accurate. In order to recognise this potential error in accuracy assessment, the CV(RMSE) metric is required.

CV(RMSE) is a measure of simulation precision calculating the standard deviation of the error indicating overall uncertainty in the model. The CV(RMSE) metric communicates precision as a single percentage value indicating the overall fit of the simulation results compared to the measured results (ASHRAE, 2002). The CV(RMSE) value is always positive. The lower the value, the better the calibration (US DOE, 2008). Equations for calculating MBE and CV(RMSE) are provided in US DOE (2008).

It is unknown whether the ASHRAE Guideline 14:2002 figures were developed through research experimentation in calibration case studies or because they were simply convenient statistical metrics and their values seemed sensible. Regardless, contemporary research has proven them to be appropriate. Bensouda (2004) supports the ASHRAE Guideline 14:2002 maximum calibration tolerances, stating that "[modelling] efforts have been quite successful in achieving simulated results that agreed with the measured consumption, typically to less than 5% on an annual basis. Agreement within 5–10% has often been achieved on a monthly basis, and sometimes on a daily basis" (Bensouda, 2004). Further evidence supporting their suitability is demonstrated by examining the level of accuracy an operational energy simulation must function to, relative to the annual operational energy savings achieved by energy conservation measures. For example, Kim (2010), investigating the energy conservation measures of building envelopes, reported that "increasing the external wall insulation by 60% will reduce the total building's energy consumption by 1.5% for high-rise buildings and 1.4% for low-rise buildings" (Kim, 2010). This is a relatively small reduction in a building's annual operational energy consumption. The risk is that, if the operational energy simulation is not operating at a high enough level of accuracy and precision, these operational energy savings would be lost in the margin of error called the performance gap.

Appendix D: Materials modelling information

This section provides information on the source and derivation of calculated indicator values by material and stage in the building life cycle. It is divided into the following sections dealing with each of the stages in the building life cycle:

- Section D1: Product stage (modules A1–A3)
- Section D2: Construction process stage (modules A4–A5)
- Section D3: Use stage (modules B2 and B4)
- Section D4: End-of-life stage (modules C1–C4)
- Section D5: Supplementary information beyond the building life cycle (module D)

D1. Product stage (modules A1 – A3)

Set out below is supporting information for the source and derivation of environmental indicators for modules A1–A3 for a range of materials that may be considered at concept or preliminary design.

Information is provided under the following headings and is organised alphabetically by product name under each heading.

Material type	List of materials modelled
D1.1 Aggregates	Granular fill
	Sand
D1.2 Reinforced concrete and cement-containing materials	Autoclaved aerated concrete (AAC) blocks
	Autoclaved aerated concrete (AAC), precast block, density 525 kg/m^3, exc. steel reinforcing.
	Autoclaved aerated concrete (AAC), precast block, density 650 kg/m^3, exc. steel reinforcing.
	Fibre cement boards
	Masonry wall, incl. concrete block 15 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing
	Masonry wall, incl. concrete block 20 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing
	Masonry wall, incl. concrete block 25 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing
	Plaster, cement
	Reinforced in-situ concrete, with ordinary Portland cement (OPC)
	Reinforced concrete, 25 MPa, composite floor decking, trapezoidal deck section 75 mm deep troughs at 300 mm ctrs, 125 mm thick in-situ slab, inc. 100 kg/m3 steel reinforcing, (OPC)
	Reinforced in-situ concrete with secondary cementitious replacements
	Reinforced precast concrete made with Ordinary Portland Cement (OPC)
	Reinforced precast concrete made with secondary cementitious replacements
	Reinforced precast double-tee units with secondary cementitious replacements
D1.3 Glass	Glass, heat strengthened
	Glass, heat strengthened, low-E
	Glass, laminated
D1.4 Insulation	Glass wool

	Mineral wool Polyester Polystyrene expanded (EPS) Polystyrene extruded (XPS)
D1.5 Membrane systems	Bentonite Bitumen, fibre reinforced Polyethylene (PE) & polyethylene, vapour barrier Polyvinyl chloride (PVC) Synthetic rubber (EPDM)
D1.6 Metals and metal-containing composites	Aluminium (anodised finish, one side 0.02 mm), extruded glazing frame, 2.0 mm BMT Aluminium (anodised finish, one side 0.02 mm), flat sheet, 0.7 mm BMT Aluminium (anodised finish, one side 0.02 mm), flat sheet, 0.9 mm BMT Aluminium (anodised, one side 0.02 mm), profile sheet metal, generic all profiles, 0.7 mm BMT Aluminium (anodised, one side 0.02 mm), profile sheet metal, generic all profiles, 0.9 mm BMT Aluminium (anodised finish, one side 0.02 mm), louvre blades, 2.0 mm BMT Aluminium (powder coated finish, one side 0.08 mm), extruded glazing frame, 2.0 mm BMT Aluminium (powder coated finish, one side 0.08 mm), flat sheet, 0.7 mm BMT Aluminium (powder coated finish, one side 0.08 mm), flat sheet, 0.9 mm BMT Aluminium composite material (ACM) panel, 4 mm thick Steel, structural, columns and beams Stud wall system, steel (galvanised finish, two sides, 0.02 mm each), 92.1x33.1 0.55 BMT @ 300ctrs, wall height 4.4-8.8 m, 1 nogging row Stud wall system, steel (galvanised finish, two sides, 0.02 mm each), 92.1x33.1 0.55 BMT @ 450ctrs, wall height 4.4-8.8 m, 1 nogging row Stud wall system, steel (galvanised finish, both sides, 0.02 mm each), 150x33.1 0.75 BMT @ 800ctrs, wall height 4.4-8.8 m, 1 nogging row Steel (galvanised finish, both sides, 0.02 mm each), profile metal sheet, generic all profiles, 0.4 mm BMT Steel (150 g/m^2 zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, 0.55 mm BMT Steel (150 g/m^2 zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, 1.2 mm BMT Steel (150 g/m^2 zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, factory paint finish both sides, 0.4 mm BMT Steel (200g/m^2 zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, factory paint finish both sides, 0.4 mm BMT
D1.7 Paint	Paint, water-borne, exterior Paint, water-borne, exterior masonry Paint, water-borne, primer/sealer
D1.8 Plasterboard	Gypsum plasterboard
D1.9 Renewable energy infrastructure (on site)	Energy generation, photovoltaic (PV) system (incl. roof mounts), 3kW

D1.10 Timber and engineered wood	Cross laminated timber (CLT) Glued laminated timber (Glulam) I-joist profile, 200x45 I-joist profile, 300x63 I-joist profile, 300x90 I-joist profile, 360x90 I-joist profile, 200x45 I-joist profile, 240x46 I-joist profile, 240x90 I-joist profile, 360x63 I-joist profile, 400x90 Laminated veneer lumber (LVL) Plywood Post tensioned timber frame structure, laminated veneer lumber (LVL), inc. steel reinforcing Timber, soft wood, sawn kiln-dried sections

D1.1 Aggregates

Product code	Product name
	Granular Fill
Description	Gravel obtained by blasting and/or excavating which may be crushed and then screened by size.
Platform/source(s) of data	EcoInvent 3.1, adapted
Data characteristics	Based on "Gravel production, crushed", adapted to include use of NZ Grid medium voltage electricity (Sacayon Madrigal, 2016) and combustion of diesel checked to ensure appropriate sulphur content (10 ppm).
Age	Process data varies with dataset – see www.ecoinvent.org.
Technology coverage	Quarried stone is crushed and sorted.
Geographical coverage	NZ for Grid electricity. Rest of the World/Global for other datasets.
Assumptions	Fill material derived from a manufactured process requiring crushing. If the source of fill does not require crushing or is from a recycled source, impacts are likely to be less.
Completeness/ exclusions	See www.ecoinvent.org
Plausibility check	Calculated greenhouse gas impact of 0.0056 kg CO_2 eq./kg compare to 0.003 kg CO_2 eq./kg for hardfill (Alcorn, 2010) and 0.0052 kg CO_2 eq./kg for general aggregate in Hammond & Jones (2011).
Consistency e.g. with EN 15804	See www.ecoinvent.org

Product code	**Product name**
	Sand
Description	Excavated material that is finer than gravel
Platform/source(s) of data	EcoInvent 3.1, adapted.

Data characteristics	Based on EcoInvent 3.1 dataset "Gravel and sand quarry operation". All electricity flows summed and attributed to NZ Grid electricity (medium voltage), based on Sacayon Madrigal (2016). Sulphur content of diesel checked to meet NZ requirements of 10 ppm. Other flows unadjusted.
Age	Various – see www.ecoinvent.org
Technology coverage	Quarrying of sand to quarry gate.
Geographical coverage	Based on Rest of the World (RoW) dataset in EcoInvent 3.1 (outside Europe). Supporting data are Global except Grid electricity (medium voltage), which is NZ.
Assumptions	See www.ecoinvent.org
Completeness/ exclusions	Data derived based on an allocation between sand and gravel produced at the quarry. See www.ecoinvent.org.
Plausibility check	Comparison with thinkstep and EcoInvent 3.1 databases, Alcorn (2010) [hardfill] and Hammond & Jones (2011) show a greenhouse gas impact in the range 0.002 – 0.005 kg CO_2 eq/kg sand. Adapted dataset is within this range being 0.0027 kg CO_2 eq/kg sand).
Consistency e.g. with EN 15804	See www.ecoinvent.org

D1.2 Reinforced concrete and cement-containing materials

Product code	Product name
	Autoclaved aerated concrete (AAC) blocks **Autoclaved aerated concrete (AAC), precast block, density 525kg/m^3, exc. steel reinforcing** **Autoclaved aerated concrete (AAC), precast block, density 650kg/m^3, exc. steel reinforcing**
Description	AAC is a lightweight, precast concrete with a cellular or foam structure.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Adapted from dataset "Aerated autoclaved concrete block production", including addition of medium voltage NZ Grid electricity (Sacayon Madrigal, 2016).
Age	See www.ecoinvent.org
Technology coverage	Raw materials (sand/gravel, quicklime, anhydrite, cement and aluminium powder) are mixed with water and poured into a mould. From the resulting reaction, hydrogen is released producing pores with a diameter of 2 - 3 mm. Includes the raw materials, their transport to the finishing plant, the energy for the autoclaving process, the packaging, the infrastructure and the disposal of wastewater and some solid household (e.g. packing material) waste
Geographical coverage	3 suppliers of AAC blocks in New Zealand, 2 of which manufacture in New Zealand and the third importing from Australia. Base data adapted for New Zealand. Electricity use divided two thirds NZ Grid electricity (Sacayon Madrigal, 2016) and one third Australia Grid electricity, in the absence of market share information. Production of sand and diesel combustion data adapted for New Zealand. All other data – Rest of the World (RoW) in EcoInvent (outside Europe).
Assumptions	Hardening is assumed to be by air-drying.

	The lifespan of the plant is assumed to be 50 years.
Completeness/ exclusions	Density of manufactured product not provided but assumed to be 445 kg/m^3 based on similar product. Lifting of blocks onto transport and any packaging or pallets used not separately modelled, so assumed this is included within the data.
Plausibility check	Modelled results compared to other data sources, these being thinkstep, EcoInvent 3.1, Hammond & Jones (2011) and published EPDs (Turk Ytong Sanari AS (2015), Xella Baustoffe GmbH (2012)). Results show good agreement with thinkstep and EcoInvent 3.1 data, but are higher than reported by Hammond & Jones (0.24 – 0.375 kg CO_2 /kg compared to 0.51 kg CO_2 eq./kg). Modelled results also show reasonable comparison with reviewed EPDs for most indicators.
Consistency e.g. with EN 15804	Based on EcoInvent.

Product code	Product name
	Fibre cement boards
Description	A board, sheet or profile product consisting of Ordinary Portland Cement (OPC) with cellulose fibres, sand and water, used primarily for claddings, roofing and wall linings.
Platform/source(s) of data	Data derived from Nebel, Alcorn and Wittstock (2011)
Data characteristics	Aggregated data.
Age	2007
Technology coverage	Proportions of constituent materials (cement, sand, wood fibre) adopted from Alcorn (2010).
Geographical coverage	New Zealand
Assumptions	No information.
Completeness/ exclusions	No information.
Plausibility check	Results compared to other data sources, specifically: ICE database (Hammond & Jones; 2011. Alcorn (2010). EPDs (Hume Cemboard Industries Sdn Bhd (2014), Eternit-Werke Ludwig Hatschek (2013), UAC Berhad (2013)) Good agreement between results used in this work and Alcorn (2010), Hume Cemboard and UAC Berhad, for which density of product is in the range 1350 – 1400 kg/m^3. Eternit Werke results larger, but relate to a denser product (1550 – 1900 kg/m^3).
Consistency e.g. with EN 15804	Good agreement with other published sources of data (see Plausibility Check). Not necessarily entirely consistent with EN 15804.

Product code	Product name
	Masonry wall, incl. concrete block 15 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing **Masonry wall, incl. concrete block 20 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing** **Masonry wall, incl. concrete block 25 series (17.5 MPa OPC), grouted 22 MPa (OPC), inc. steel reinforcing**
Description	Hollow concrete block walls consist of hollow concrete blocks, a grout infill and steel reinforcement. Quantity of steel reinforcement based on NZS4299.
Platform/source(s) of data	EcoInvent 3.1, adapted
Data characteristics	Based on "Concrete block production", adapted to include use of NZ Grid electricity (medium voltage), derived from Sacayon Madrigal (2016). Steel reinforcement manufacture uses EcoInvent 3.1 data.
Age	See www.ecoinvent.org for EcoInvent data. NZ Grid electricity from 2013 data (Sacayon Madrigal, 2016).
Technology coverage	Ready mixed concrete is poured into a mould, after which it is air dried and then packed ready for transport. The concrete blockwork wall comprises hollow concrete blocks with reinforcement, with grout poured to fill voids.
Geographical coverage	Concrete mix designs based on Allied Concrete data. Reinforcement based on EcoInvent data, adapted to include use of New Zealand Grid electricity (Sacayon Madrigal, 2016). Supporting EcoInvent data from "Rest of the World (RoW)" (outside Europe).
Assumptions	Original EcoInvent data implies use of 50 MPa concrete (0.00042 m^3 needed to make 1 kg blocks = density of 2380 kg/m^3 = 50 MPa. To produce a hollow concrete block wall with a strength of 12 MPa, a 17.5 MPa ready mix concrete is used to make blocks, and included with 22 MPa grout infill (with reinforcing). This is consistent with Section 3.1 of the NZ Concrete Masonry Manual (2012), which is drawn from NZS 4230. Therefore, the volume of concrete to make 1 kg blocks in the original EcoInvent dataset was adjusted according to the density of 17.5 MPa concrete = 0.0004273 m3 (based on density of 17.5 MPa ready mixed concrete in Allied Concrete (2014)). Another assumption is that the ready mixed concrete is made at the same site as production of blocks, so no additional transport of concrete to the block yard is considered. Concrete wastage is per data embedded in Allied Concrete data, and no subsequent wastage of blocks before shipment is assumed. Grout data based on 20 MPa ready mixed concrete data using mix design from Allied Concrete (2014). Grout has an absence of coarse aggregate and use of a higher proportion of fine aggregate, therefore use of data for in situ concrete is an approximation. For 12 MPa infilled blocks, grout with a compressive strength of 22 MPa is used in combination with concrete blocks of 17.5 MPa, based on New Zealand Concrete Masonry Association (2012) derived from NZS4230.
Completeness/ exclusions	Infrastructure required for block manufacture, other than that associated with ready mixed concrete production.

	Lifting of the product onto trucks for despatch, any packaging or use of pallets assumed to be included in the original EcoInvent dataset on which the data are based. Mortar in joints between concrete blocks excluded.
Plausibility check	Greenhouse gas results are around 0.13 kg CO_2 e/kg (regardless of series) for reinforced and grouted concrete blockwork. For comparison purposes, Alcorn (2010) reports 0.112 kg CO_2 /kg for concrete block only. Data in EcoInvent show higher greenhouse gas values than calculated here but appear to be made from higher compressive strength concrete.
Consistency e.g. with EN 15804	Based on EcoInvent.

Product code	**Product name**
	Plaster, Cement
Description	Cementitious plasters contain cement and sand. Many are mixed on site.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Rest of World data for base plaster production.
Age	Various – see www.ecoinvent.org
Technology coverage	Includes all manufacturing required to make cementitious plaster, including infrastructure.
Geographical coverage	Rest of the World (outside Europe).
Assumptions	Calculated indicators are for a dry plaster mix which is subsequently combined with water at the construction site in the ratio 6 parts plaster to 1 part water (assuming use of good quality sand, according to NZS4251.1). Therefore the dry plaster contributes 0.857 kg per kg of wet plaster.
Completeness/ exclusions	See Technology coverage. Does not include packaging (or addition of water, which happens at the construction site in module A5).
Plausibility check	Hammond & Jones (2011) report embodied carbon of 0.13 kg CO_2 eq./kg, noting a wide range of values for which this is at the lower end. The figure calculated for this work is 0.27 kg CO_2 eq./kg, considerably higher. Calculated total primary energy in this work of 1.84 MJ/kg are comparable with the figure cited by Hammond & Jones (2011).
Consistency e.g. with EN 15804	See www.ecoinvent.org

Product code	Product name
	Reinforced in-situ concrete, with ordinary Portland cement (OPC). *Separate materials for all variations of compressive strengths (17.5 MPa, 20, 25, 30, 35, 40, 45, and 50 MPa), reinforcing steel quantities (50 kg/m3, 100, 150, and 200 kg/m3), and for secondary cementitious replacements (25%, 50%, and 75% GGBS, and 20% and 35% PFA).* Example materials: Concrete, 17.5 MPa, in-situ, no reinforcement, (OPC) Concrete, 20.0 MPa, in-situ, no reinforcement, (OPC) **Reinforced concrete, 25 MPa, composite floor decking, trapezoidal deck section 75 mm deep troughs at 300 mm ctrs, 125 mm thick in-situ slab, inc. 100 kg/m^3 steel reinforcing, (OPC)** *Variations for in-situ slab strength (25, 30, 35, 40, 45, and 50 MPa) slab thickness, deck sections size (75, 95 mm), and reinforcement content (100, 150 kg/m3).*
Description	Represents reinforced concrete made with pump and standard grades of Normal ready mixed concrete (as defined in NZS 3104) reaching age at 28 days, with reinforcement.
Platform/source of data	Allied Concrete/EcoInvent 3.1/AusLCI/MAF (2014)
Data characteristics	Concrete mixes based on Allied Concrete (2014). Ordinary Portland cement production based on AusLCI data (http://alcas.asn.au/AusLCI/) for manufacture of cement using a dry process. Other processes use EcoInvent 3.1 data including: Gravel production, crushed (adapted with NZ electricity). Sand quarry operation (adapted with NZ electricity). Tap water production, conventional treatment. Reinforcement production (adapted with NZ electricity). Data for Admixtures based on indicators reported in an EPD for water resisting admixtures by EFCA (2015). New Zealand Grid electricity (medium voltage) based on Sacayon Madrigal (2016).
Age	2013 data for mix designs. Process data varies with dataset – see www.ecoinvent.org (and AusLCI for cement data).
Technology coverage	Covers batching plant operations (central mix and dry batch) at 28 sites in the North and South Islands of New Zealand. Includes cement, aggregate, sand and admixture production and transport to the batching plants, plus delivery of water for use in concrete mixes and for washing trucks etc. Use of electricity and diesel at the batching plants is included, as is transport and disposal of generated wastes. Data for reinforcement based on primary production in New Zealand (since the closure of the electric arc furnaces at Pacific Steel). Reinforcement amounts are based on typical values that may be used in engineering practice, up to approximately 2% by volume (based on estimates from BRANZ structural engineers).
Geographical coverage	Mix designs and batching plant operations based on New Zealand data (Allied Concrete, 2014). Grid electricity (medium voltage) based on the New Zealand Grid in 2013, using a model developed by Sacayon Madrigal (2016).

	Supporting data uses Rest of the World (RoW) data in EcoInvent 3.1 ie. outside Europe. Reinforcement production based on EcoInvent RoW data (adapted to include use of NZ Grid electricity).
Assumptions	All water obtained from the reticulated network. In practice, batching plants also collect rainwater which is not taken into account. Allied Concrete have an EPD published for ready mixed concrete supplied by Holcim cement. This EPD is based primarily on cement from Holcim's Westport plant. Data in the EPD have not been used because: The Westport cement plant operates a "wet process" in which limestone is ground with water to make a fine slurry. This is then dried and heated in a rotary kiln. The need to drive off the water means that wet process plants use more energy than dry process cement plants. Thus, the contribution of the wet process can be considered to be at the high end of impacts of cement production. Holcim has announced the closure of the Westport plant, meaning that use of these data would not necessarily be representative of operations in 2016 onwards. Instead, a generic concrete model has been developed, which additionally allows calculation of impacts for concretes with cement replacement materials such as ground granulated blast furnace slag (GGBS) and pulverised fly ash (PFA). It is assumed that half of the cement is imported (travelling a one way distance of 5000 km) and half is produced domestically.
Completeness/ exclusions	Return truck journeys for materials brought to the batching plant. Any packaging associated with materials brought to the batching plant. A1 – A3 data are calculated for reinforced concrete with reinforcement, even though these are not physically combined until at the construction site (in module A5). Indicators calculated based on the mass of concrete and steel per cubic metre of reinforced concrete, normalised to 1 kg of reinforced concrete.
Plausibility check	Ready mixed concrete Calculated environmental indicators for ready mixed concrete are, in general, lower than those reported in Allied Concrete (2014). This is primarily because the Allied Concrete EPD is based on Holcim cement supplied by the Westport plant. This plant uses a less energy efficient "wet process" in comparison with an alternative dry process plant. Calculated greenhouse gas results for ready mixed concrete in comparison with figures cited in the ICE Database by Hammond & Jones (2011) for the UK are summarised below:

Comp strength (MPa)	Modelled (kg CO_2 eq./kg)	ICE (2011) (kg CO_2 eq./kg)
17.5	0.109	0.123
20	0.113	0.123 – 0.132
25	0.123	0.132 – 0.14
30	0.133	0.14 – 0.148
35	0.149	0.148 – 0.163
40	0.172	0.163 – 0.188
45	0.181	0.188
50	0.203	0.188

	Differences are likely to arise from the amount of cement in each mix and the source(s) of cement. Alcorn (2010) reports 0.118 and 0.164 kg CO_2 eq/kg for 17.5 and 30 MPa compressive strengths respectively. Steel reinforcement Concrete may contain steel reinforcing bar (rebar) or steel mesh which is used to resist tensile or shear forces (CCANZ, 2010). Amounts of reinforcement present in concrete varies depending on the reinforced concrete application, such as floor slabs, beams, columns or walls, with minimum amounts based on NZ3101. Results have been calculated based on a steel content of 50, 100, 150 and 200 kg/m^3 reinforced concrete. Data used for reinforcing is based on primary production in New Zealand (since production using electric arc furnaces at Pacific Steel recently ceased). The process is modelled using EcoInvent 3.1 data for reinforcement production, adapted to incorporate use of New Zealand Grid electricity. Nebel, Alcorn and Wittstock (2011) report 0.45 kg CO_2 eq./kg for steel reinforcing made using electric arc furnaces based primarily on a scrap steel input. This compares with 2.25 kg CO_2 eq./kg calculated in this work, based on primary production of reinforcement. Results per kg with different levels of reinforcing are provided in module A1–A3 (even though for in-situ concrete applications, the reinforcing is added to the concrete at the construction site). Reinforced concrete Calculated greenhouse gas results for reinforced concrete (reinforcement at 100 kg/m^3) in comparison with figures from Hammond & Jones (2011) for the UK are summarised below:

Comp strength (MPa)	Modelled (kg CO_2 eq./kg)	ICE (2011) (kg CO_2 eq./kg)
17.5	0.2	0.2
20	0.2	0.2 – 0.209
25	0.21	0.209 – 0.217
30	0.22	0.217 – 0.225
35	0.24	0.225 – 0.24
40	0.26	0.24 – 0.265
45	0.27	0.265
50	0.29	0.265

	Results show good agreement.
Consistency e.g. with EN 15804	See www.ecoinvent.org.

Product code	**Product name**
	Reinforced in-situ concrete with secondary cementitious replacements. Separate materials for all variations of compressive strengths (17.5 MPa, 20, 25, 30, 35, 40, 45, and 50 MPa), reinforcing steel quantities (50 kg/m3, 100, 150, and 200 kg/m3), and for secondary cementitious replacements (25%, 50%, and 75% GGBS, and 20% and 35% PFA). **Example:**

	Reinforced concrete, 17.5 MPa, in-situ, inc. 50 kg/m3 steel reinforcing, (25% GGBS) Reinforced concrete, 17.5 MPa, in-situ, inc. 50 kg/m3 steel reinforcing, (50% GGBS) Reinforced concrete, 17.5 MPa, in-situ, inc. 50 kg/m3 steel reinforcing, (75% GGBS) Reinforced concrete, 17.5 MPa, in-situ, inc. 50 kg/m3 steel reinforcing, (20% PFA) Reinforced concrete, 17.5 MPa, in-situ, inc. 50 kg/m3 steel reinforcing, (35% PFA)
Description	Represents reinforced concrete made with pump and standard grades of ready mixed concrete comprising supplementary cementitious material (SCM) as a direct replacement for cement plus reinforcement. The replacement level of SCM defined in NZS 3122 for blended cements are as follows. Fly ash or pozzolan: 10% – 35%. Ground granulated blast furnace slag: 10% - 75%. Amorphous silica: up to 10%.
Platform/source of data	Allied Concrete/EcoInvent 3.1/AusLCI
Data characteristics	Original mixes based on Allied Concrete data. GGBS substitutes 25%, 50% and 75% of cement. PFA substitutes 20% and 35% cement. Reinforcement content based on BRANZ structural engineer estimates for typical and maximum quantities. Processes use EcoInvent 3.1 and AusLCI data (see *Concrete in situ*).
Age	2013 data for mix designs. Data for reinforcement based on EcoInvent 3.1 data, adapted with New Zealand Grid electricity. Process data varies with dataset – see www.ecoinvent.org.
Technology coverage	GGBS is a product of blast furnace slag made at steel plants. Data are based on AusLCI http://alcas.asn.au/AusLCI/. Fly ash is obtained as a result of cleaning of flue gas at large coal fired power plants. Data are also based on AusLCI http://alcas.asn.au/AusLCI/. Both products are assumed to be imported to New Zealand and are transported 10,000 km by ship and 50 km by truck (one way). For production of concrete and reinforcement, see **Reinforced in-situ concrete with ordinary Portland cement**.
Geographical coverage	Concrete mix design data from New Zealand. Reinforcement data based on EcoInvent, adapted to reflect use of New Zealand Grid electricity. GGBS and PFA data from Australia.
Assumptions	GGBS and PFA assumed to replace cement on a 1:1 basis. No other changes to the concrete are taken into account. In a worldsteel report (2014), 1 tonne of GGBS typically replaces 0.9 – 1 tonne of cement.
Completeness/ exclusions	Return truck journeys. Any packaging materials.
Plausibility check	Calculated greenhouse gas results (without reinforcement) in comparison with figures cited in the ICE Database by Hammond & Jones (2011) for the UK are summarised below. The percentage figures refer to cement replacement by PFA and all results are in kg CO_2 eq./kg:

Comp strength (MPa)	Model (20%)	ICE (15%)	Model (35%)	ICE (30%)
17.5	0.092	0.112	0.078	0.1
20	0.095	0.112 – 0.122	0.081	0.1 – 0.108
25	0.103	0.122 – 0.13	0.088	0.108 – 0.115
30	0.111	0.13 – 0.138	0.095	0.115 – 0.124
35	0.124	0.138 – 0.152	0.106	0.124 – 0.136
40	0.144	0.152 – 0.174	0.122	0.136 – 0.155
45	0.151	0.174	0.128	0.155
50	0.169	0.174	0.144	0.155

Calculated greenhouse gas results for 25% and 50% cement replacement by GGBS are provided below, for comparison with figures cited in the ICE Database by Hammond & Jones (2011) for the UK. The percentage figures refer to cement replacement by GGBS and all results are in kg CO_2 eq./kg:

Comp strength (MPa)	Model (25%)	ICE (25%)	Model (50%)	ICE (50%)
17.5	0.089	0.096	0.07	0.07
20	0.092	0.096 – 0.104	0.072	0.07 – 0.077
25	0.101	0.104 – 0.111	0.078	0.077 – 0.081
30	0.109	0.111 – 0.119	0.084	0.081 – 0.088
35	0.121	0.119 – 0.133	0.094	0.088 – 0.1
40	0.140	0.133 – 0.153	0.108	0.1 – 0.115
45	0.148	0.153	0.114	0.115
50	0.165	0.153	0.127	0.115

PFA results do not match in terms of level of substitution for cement and are consistently lower than results presented by Hammond & Jones. The magnitude of difference decreases with increasing compressive strength.

Comparison of ground granulated blast furnace slag data shows good agreement.

Consistency e.g. with EN 15804	AusLCI data used for GGBS and PFA for consistency. GGBS data are based on economic allocation. Alternatively, worldsteel (2014) has published EN 15804 compliant data for blast furnace slag production, which only includes an estimate for granulating. In these data, the steel making process, and resulting impacts, are allocated to blast furnace slag based on physical partitioning.

Product code	Product name
	Reinforced precast concrete made with Ordinary Portland Cement (OPC) **Reinforced precast concrete made with secondary cementitious replacements.** Separate materials for 30 MPa and 45 MPa compressive strengths, reinforcing steel quantities (50, 100, 150, and 200 kg/m^3), and for secondary cementitious replacements (25%, 50%, and 75% GGBS, and 20% and 35% PFA). Example: Reinforced concrete, 30 MPa, precast, inc. 50 kg/m^3 steel reinforcing, (25% GGBS).
Description	Precast concrete may be made away from the construction site or may be made at the construction site as "tilt slab"), by pouring ready mixed concrete into forms where it is left to cure. In-situ concrete of compressive strengths 30 MPa or 45 MPa is typically used (e.g. Beattie, 2007) with steel reinforcement. These data assume that precast elements are made off-site.
Platform/source(s) of data	Based on *Concrete 30 MPa, in situ* and *Concrete 45 MPa, in situ.* Variants using supplementary cementitious materials (SCMs) based on *Concrete (blended – 20% PFA) in situ, Concrete (blended – 35% PFA) in situ, Concrete (blended – 25% GGBS) in situ, Concrete (blended – 50% GGBS) in situ* and *Concrete (blended – 75% GGBS) in situ* for 30 MPa and 45 MPa compressive strengths. Includes lifting of the precast elements from forms onto trucks for transport (see *Concrete and cement-containing materials* in Section B on lifting for approach).
Data characteristics	See *Reinforced in-situ concrete*.
Age	See *Reinforced in-situ concrete*.
Technology coverage	Based on off-site production, with subsequent transport to the construction site (not included here).
Geographical coverage	See *Reinforced in-situ concrete*.
Assumptions	Based on 30 MPa or 45 MPa ready mixed concrete.
Completeness/ exclusions	Plant and infrastructure for precasting yard including the forms into which ready mixed concrete is poured. Use of consumables and energy, beyond that associated with production of ready mixed concrete.
Plausibility check	See *Reinforced in-situ concrete*.
Consistency e.g. with EN 15804	See *Reinforced in-situ concrete*.

Product code	Product name
	Reinforced precast double-tee units with secondary cementitious replacements. Separate materials for all variations of secondary cementitious replacements (25%, 50%, and 75% GGBS, and 20% and 35% PFA), and for the different unit series sizes (200, 250, 300, 350, 400, 450, 500, 550, and 600 series). **Example:**

	Reinforced concrete, 45 MPa, precast double-tee, inc. 200 kg/m3 steel reinforcing, 200 series, (25% GGBS)
Description	Double tees are a precast prestressed concrete flooring system that is frequently used as an upper floor system and has the advantage of being capable of providing wide spans. They come in different sizes (for example, 200, 250, 300, 400, 450, 500, 550, and 600 mm tee sizes), with each double tee unit consisting of a horizontal flange and two vertical webs so that, in profile, they look like two capital "Ts" (thus giving them their name). Usually, a minimum of a 50 mm layer of reinforced 25 MPa in-situ concrete is poured over the top of a double tee system to provide the floor.
Platform/source(s) of data	Based on *Reinforced in-situ concrete (45 MPa).* For options using supplementary cementitious material (SCMs) of ground granulated blast furnace slag (GGBS) or pulverised fly ash (PFA), see *Reinforced in-situ poured concrete with secondary cementitious replacements.*
Data characteristics	Uses same data as for *Concrete 45 MPa, Precast* (with a steel content of 200 kg/m^3).
Age	Varies with dataset – see www.ecoinvent.org
Technology coverage	Steel strands are prestressed and steel stirrups placed in a form which is filled with 45 MPa in-situ concrete and left to cure. Once installed, a layer of reinforced concrete is added. The thickness of this layer can vary but is a minimum of 50 mm, and is 25 MPa (from Stresscrete product information[17]). This is not included in the data for Double Tees, but can be added using the *Concrete in situ* data.
Geographical coverage	Rest of the World (RoW) being outside Europe i.e. not New Zealand specific.
Assumptions	Made with 45 MPa in-situ concrete (from Stahlton Product Data Sheet)[18]. From calculation (based on Stahlton Product Data Sheet), double tees contain approximately 200 kg/m^3 steel. All indicators provided with this steel content. Includes energy required to lift double tees. We assume a lift of 6 m using a diesel powered crane.
Completeness/ exclusions	Infrastructure associated with double tee production.
Plausibility check	See *Reinforced in-situ concrete*
Consistency e.g. with EN 15804	See *Reinforced in-situ concrete*

D1.3 Glass

Product code	Product name
	Glass, Heat Strengthened **Glass, Heat strengthened, Low-E** **Glass, Laminated**
Description	Glass is made by combining and heating silica sand, lime and soda before passing over a bed of molten tin followed by controlled cooling. It is normally produced in thicknesses ranging from 2 mm up to 25 mm.

[17] www.stresscrete.co.nz
[18] www.stahlton.co.nz

	Float glass may undergo subsequent treatment such as heat strengthening, coating and laminating.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Heat strengthened glass based on "Flat glass production" and "Tempering, flat glass". Heat strengthened, low E glass based on "Flat glass production, coated" and "Tempering, flat glass". Laminated glass uses an adapted version of "Glazing production, double, U<1.1 W/m^{2}K, laminated safety glass". The original dataset has an input of "Glazing production, double, U <1.1 W/m2K" which includes frame and other elements. These have been removed including aluminium, argon, polybutadiene, polysulphide and zeolite. Statistics NZ data indicate that 68% by value of total imports from 2010 – 2015 of "glass: multiple walled insulating units of glass" came from Singapore followed by USA (14%), China (9%) and Europe (9%). Therefore, electricity required for production is based on the Singapore grid, which is 95.5% supplied by natural gas (Energy Market Authority, 2015).
Age	Various – see www.ecoinvent.org.
Technology coverage	Includes provision of cullet, melting and forming in a float bath, cooling, cutting and storage. Also includes infrastructure. Heat strengthened glass involves a toughening process that may be physical (thermal) or chemical. Data in EcoInvent are based on a thermal tempering process. Low E glass includes cathodic sputtering of a metal coating on the float glass. Laminated glass – includes processes to make a double glazed unit consisting of laminated safety glass with an area of 1.06 m^2.
Geographical coverage	Rest of the World data in EcoInvent 3.1 ie. outside Europe. Laminated safety glass – electricity use based on the Singapore grid.
Assumptions	See www.ecoinvent.org
Completeness/ exclusions	Excludes any packaging used.
Plausibility check	Alcorn (2010) reports an embodied carbon dioxide figure of 2.45 kg CO_2 eq./kg and 27 MJ/kg for the embodied energy of toughened glass. Hammond & Jones (2011) report 1.35 kg CO_2 eq./kg and 23.5 MJ/kg for toughened glass, which are closer to the data used here based on EcoInvent 3.1 of 1.22 kg CO_2 eq./kg and 14.6 MJ/kg (for heat strengthened glass). A report by PE International for Glass for Europe reports 1.23 kg CO_2 eq./kg of float glass (without heat strengthening). The report also provides a primary energy demand of 15.62 MJ/kg.
Consistency e.g. with EN 15804	See www.ecoinvent.org

D1.4 Insulation

Product code	Product name
	Insulation, glass wool
Description	Insulation product made primarily from recycled glass which is melted at high temperature and spun into fibres to form a blanket or mat.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Original unit process dataset in EcoInvent 3.1 is "Glass wool mat production". Adapted for recycled content, use of NZ Grid electricity (based on Sacayon Madrigal (2016)) and check to ensure diesel combustion has a sulphur content of 10 ppm.
Age	Various – see www.ecoinvent.org. NZ Grid electricity data based on 2013 fuel mix.
Technology coverage	Glass wool insulation is manufactured in New Zealand, and may consist of a minimum of 80% recycled content (Source: Tasman website). No NZ data available, so EcoInvent 3.1 data used, adapted for New Zealand. Adaptations as follows: Use of NZ Grid electricity, medium voltage. Recycled content input adjusted to 80% by mass.
Geographical coverage	Rest of the World data in EcoInvent 3.1 (outside Europe).
Assumptions	Process represented in EcoInvent 3.1 is similar to NZ manufacture, with adjustments set out in Technology coverage.
Completeness/ exclusions	Transport of recycled glass to the insulation plant is not included. No packaging considered.
Plausibility check	Results are lower than published EPD data (Isover Saint Gobain, 2015a, b, c), potentially because of the high proportion of renewables supplying NZ Grid electricity (electricity makes the largest contribution to greenhouse gas emissions at 26%) and the high recycled glass content (the EPDs cover product without apparent recycled glass content). Calculated greenhouse gas results are similar to Nebel, Alcorn and Wittstock (2011), with a 4% difference. Hammond & Jones (2011) shows good agreement, but only presents results for carbon dioxide emissions. Total primary energy of 30 MJ/kg is similar to the figure of 32 MJ/kg quoted by Alcorn (2010) and within the range provided in Hammond & Jones (2011).
Consistency e.g. with EN 15804	The end of waste state of recycled glass is taken as the point at which recycled glass arrives at the glass wool plant.

Product code	Product name
	Insulation, mineral wool
Description	Insulation product primarily made from inorganic rocks which are melted at high temperatures and spun into fibres to form a blanket or mat.
Platform/source(s) of data	Knauf (2014)
Data characteristics	Data from an EPD for a specific European plant.
Age	EPD published in 2014.

Technology coverage	Insulation available as slabs, boards and also rolls. Density range is 25 to 160 kg/m³ (with 50 kg/m³ for results published in the EPD). Product consists of inorganic rocks (typically 98%) of stone wool and thermosetting resin binder. The inorganic part is made of volcanic rocks, typically basalt, and also dolomite, with a small amount of mineral wool waste (internal and external), with cement. The process uses a cupola furnace heated by coke.
Geographical coverage	Knauf (2014) covers manufacture in Slovenia. Mineral wool insulation is not manufactured in New Zealand.
Assumptions	Manufacture at the Knauf Slovenia plant is representative of manufacture at plants form which mineral wool is imported to New Zealand.
Completeness/ exclusions	Data options include EcoInvent 3.1 data set "RoW rock wool production, packed" or Knauf (2014), based on a manufacturing plant in Slovenia. EcoInvent dataset has no waste flows and density of product is unknown. Therefore, Knauf (2014) data selected.
Plausibility check	Greenhouse gas and total primary energy results are higher than quoted in Hammond & Jones (2011) and approximately 10% higher (for greenhouse gases) than the EcoInvent dataset results. Results in another EPD (Rolan, 2014) are the lowest found. Input material for this process is 70% recycled which is likely to account for the lower presented figure.
Consistency e.g. with EN 15804	Data developed consistent with EN 15804 standard.

Product code	**Product name**
	Insulation, polyester
Description	Insulation material based on petrochemicals which is either heat treated or has binding agents added. Product made in New Zealand contains recycled PET (polyethylene terephthalate) bottles.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Original unit process dataset is "Fleece production, polyethylene". In the absence of NZ data, EcoInvent 3.1 data used, adapted for New Zealand as follows: Use of NZ Grid electricity, medium voltage, based on Sacayon Madrigal (2016). Recycled content input adjusted to 45% by mass.
Age	Various for EcoInvent data – see www.ecoinvent.org
Technology coverage	Polyester insulation is manufactured in New Zealand, where polyester fibre is used and may contain a minimum of 45% recycled content (Source: Autex website).
Geographical coverage	Global data in EcoInvent 3.1.
Assumptions	EcoInvent data, adapted as indicated in Data Characteristics, is representative of New Zealand manufacture.
Completeness/ exclusions	See www.ecoinvent.org
Plausibility check	Freudenberg (2015) provides a greenhouse gas impact of 1.8 kg CO_2 e/kg for a product with 75% recycled content. This work calculates the same impact for a product with 45% recycled content.

	Calculated total primary energy is higher at 60 MJ/kg compared to 42 MJ/kg reported by Freudenberg (2015).
Consistency e.g. with EN 15804	Includes transport and processing of collected PET bottles for input to the process, so the end of waste state is set prior to this collection.

Product code	**Product name**
	Insulation, polystyrene expanded (EPS)
Description	Expanded polystyrene is a rigid foam material made from petrochemicals. Carbon dioxide or pentane may be used as a blowing agent.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Based on "Polystyrene, expandable" in EcoInvent 3.1
Age	See www.ecoinvent.org
Technology coverage	EPS is manufactured in New Zealand using imported polystyrene beads. A low boiling point hydrocarbon, usually pentane gas, is added to the beads to assist the expansion process.
Geographical coverage	Rest of the World (RoW) data in EcoInvent ie. excluding Europe.
Assumptions	In the absence of NZ data, options were EcoInvent data (from APME) or EPD data from ANIQ (2015). Whilst the ANIQ data are more recent, the product contains almost 30% galvanised steel which is not representative of the NZ product. Therefore, EcoInvent data were used. However these contain no waste flows. Therefore, waste flows reported by ANIQ (2015) have been used. Density of product in ANIQ (2015) assumed ie. 15.9 kg/m^3.
Completeness/ exclusions	No waste data are reported, so waste data from ANIQ (2015) have been used as an estimate.
Plausibility check	Reported results in ANIQ (2015) and EcoInvent 3.1 show reasonable alignment for environmental indicators. Hammond & Jones (2011) also shows good agreement for greenhouse gas impacts (within 3%). Alcorn (2010) reports a lower greenhouse gas impact at 2.5 kg CO_2 eq./kg (compared to 3.4 kg CO_2 eq./kg used here). Reported total primary energy shows some differences, with Alcorn (58 MJ/kg), EcoInvent (83 MJ/kg), Hammond & Jones (89 MJ/kg) and ANIQ (99 MJ/kg).
Consistency e.g. with EN 15804	See www.ecoinvent.org

Product code	**Product name**
	Insulation, polystyrene extruded (XPS)
Description	Extruded polystyrene is a rigid foam material made from petrochemicals.
Platform/source(s) of data	Forman Building Systems (2013)
Data characteristics	Data reported in an EPD for plants in two European countries. See *Geographical coverage*.
Age	EPD published in 2013 based on manufacturing data from 2010.

Technology coverage	Manufacture of XPS boards within a density range from 30 to 50 kg/m³, supplied in three different compressive strength levels from 100 to 700 kPa within a thickness range of 20 to 200 mm. Covers manufacture by Dow as a weighted average of boards produced at works in Greece and Germany, being 1 m² of XPS board with a thickness of 100 mm, i.e. 0.1 m³ with a density of 35 kg/m³. Boards may have different surfaces (with extrusion skin, planed, grooved or thermally embossed and supplied with butt edge, shiplap and tongue-and-groove profiles. XENERGY is manufactured in a continuous extrusion process. Polystyrene granules are melted together with additives in the extruder under high pressure. Blowing agents are injected into the melted mass and dissolved in it. The melted mass is extruded through a flat die. The drop in pressure causes the polystyrene to foam and cool down to solidify. An endless board of homogenous closed cell polystyrene foam is produced. This is cooled further and then cut to dimensions, trimmed, the surface modified if necessary and packed. Carbon dioxide in combination with process aids is used as a blowing agent.
Geographical coverage	XPS imported into NZ. Plants covered by Forman Building Systems (2013) are based in Europe (Germany and Greece), therefore assumption is that all, or the majority of, XPS board (imported by Forman in NZ) is derived from these two plants.
Assumptions	See Geographical coverage.
Completeness/ exclusions	No significant exclusions.
Plausibility check	Results are dependent on density of product which can vary from 30-50 kg/m³. Results may be adjusted according to the ratio of the following: [Density of product to be considered/Density of product for stated results (35 kg/m³)] * [Thickness of board to be considered/Thickness of board for stated results (100 mm)]. Results adjusted for density show good alignment with other published EPDs (EXIBA, 2014; Jackon Insulation GmbH, 2015). Results lower than provided in EcoInvent 3.1 for "RoW: polystyrene production, extruded, CO_2". Comparison of EcoInvent 3.1 data shows that greenhouse gas results are heavily dependent on the blowing agent used, with significantly higher impacts arising from use of HFC 134a as a blowing agent. Results also marginally higher when HFC 152a used as a blowing agent in comparison with carbon dioxide. Alcorn (2010) shows lower results at 2.5 kg CO_2 eq./kg although density unknown so no adjustment possible.
Consistency e.g. with EN 15804	EPD compliant with EN 15804.

D1.5 Membrane systems

Product code	Product name
	Membrane, bentonite
Description	Sheet membrane consisting of two geotextile membranes needle punched together, between which is a layer of granular sodium bentonite.

Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Based on "Global" data in EcoInvent 3.1 – market for bentonite, market for fleece, polyethylene and extrusion production, plastic film. Quantities of bentonite and polyethylene based on manufacturer data.
Age	Various – see www.ecoinvent.org
Technology coverage	No data representing production of the membrane itself.
Geographical coverage	Global data – not NZ specific
Assumptions	Data are an approximation only and likely to under-represent impacts of membrane manufacture.
Completeness/ exclusions	No data for the production of the bentonite membrane itself. Only data for production of bentonite and polyethylene included.
Plausibility check	No data
Consistency e.g. with EN 15804	Data gap concerning production of the membrane. Data used for production of components based on EcoInvent data.

Product code	**Product name**
	Membrane, bitumen, fibre reinforced
Description	Waterproof membrane system produced by mixing bitumen and polymers reinforced with polyester or glass mat. The system may be fully torched by heating the bottom of the membrane, mechanically fastened by stainless steel fasteners with torching of the top layer, or ballasted, when the membrane is torched and then covered in ballast.
Platform/source(s) of data	EcoInvent 3.1, Bitumen Waterproofing Association (2013)
Data characteristics	Composition based on a multi-layer fully torched system, as defined by the Bitumen Waterproofing Association EPD for the European bitumen membrane sector. This is derived from 42 plants across 10 European countries. Product used (System 4 in Bitumen Waterproofing Association (2013)) consists of a 3.8 mm top layer with a mass of 4.8 kg per m^2 and a 3.1 mm bottom layer with a mass of 3.7 kg per m^2. Data used to represent production of materials derived from EcoInvent, including: Bitumen seal Limestone production, crushed, washed Polypropylene production, granulate Fleece production, polyethylene Extrusion production, plastic film Gravel and sand quarry operation
Age	Data collected in 2010.
Technology coverage	Most bitumen roofing used in New Zealand is 2 layer torch on. Mechanically fastened and ballasted systems are less common.
Geographical coverage	Composition based on European data. Bitumen membrane systems in New Zealand are imported from Europe, so this is reasonable.
Assumptions	Data are an approximation only and likely to under-represent impacts of membrane manufacture.
Completeness/ exclusions	Composition data accounts for 92% of inputs. Bitumen Waterproofing Association (2013) shows 8% of materials are "other" which are not

	modelled. The process for making the membrane is also missing, so impacts likely to be under-reported. No packaging included.
Plausibility check	BTC (2015) published an EPD for fibre reinforced bitumen waterproofing manufactured in Spain. This shows a greenhouse gas impact per square metre which calculates to 1 kg CO_2 eq./kg (based on the BTC Politax 40 BASIC product). In comparison, the greenhouse gas impact in this work is 0.81 kg CO_2 eq./kg (19% less). Similarly, total primary energy in BTC (2015) calculates to 42.8 MJ/kg compared to 33.4 MJ/kg in this work (22% less). This suggests that the results calculated here are under-reported.
Consistency e.g. with EN 15804	The Bitumen Waterproofing Association (2013) EPD is pre-certified for the production of Product Category Rules (PCR). Reported impacts have therefore not been used as they may potentially change. No finalised version could be found. Data gaps not compliant with cut off criteria in EN 15804.

Product code	**Product name**
	Membrane, polyethylene (PE) **Membrane (DPM), polyethylene, vapour barrier**
Description	Used as a damp proofing under concrete slabs and as a synthetic wall underlay.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Includes "Market for polyethylene, high density, granulate", "Market for extrusion, plastic film" and "Packaging film production"
Age	Various – see www.ecoinvent.org
Technology coverage	Covers production of HDPE granulate and extrusion into a sheet.
Geographical coverage	Global
Assumptions	See www.ecoinvent.org
Completeness/ exclusions	See www.ecoinvent.org. Excludes any packaging used.
Plausibility check	Greenhouse gas impact of 2.57 kg CO_2 eq./kg compares to 2.6 kg CO_2 eq./kg for the Association of Plastic Manufacturers in Europe (APME) (Athena, 1999), 2.6 kg CO_2 eq./kg for LDPE film and 1.93 kg CO_2 eq./kg for HDPE (Hammond & Jones, 2011). Total Primary Energy of 86 MJ/kg compares to 51 MJ/kg cited by Alcorn (2010) for building wrap.
Consistency e.g. with EN 15804	See www.ecoinvent.org

Product code	**Product name**
	Membrane, polyvinyl chloride (PVC)
Description	Consists of a single sheet of PVC reinforced with polyester fibre used for waterproofing.
Platform/source(s) of data	EcoInvent 3.1

Data characteristics	Based on Global/Rest of the World data in EcoInvent including "Market for polyvinylchloride, suspension polymerised", "Market for fleece, polyethylene" and "Extrusion production, plastic film".
Age	Various – see www.ecoinvent.org
Technology coverage	Data for manufacture of the membrane are missing.
Geographical coverage	Rest of the World ie. outside Europe or Global data in EcoInvent 3.1 used.
Assumptions	PVC made by suspension polymerisation as this is the most common method of manufacture (from www.pvc.org/en/p/the-pvc-production-process-explained). Proportion of PVC to polyethylene is 92% to 8% respectively, by mass. Danosa (2015) states PET fibre content of 5%.
Completeness/ exclusions	See Technology coverage. Only production of constituent materials is represented. Packaging and ancillary materials eg. used in fixing excluded.
Plausibility check	Danosa (2015) provides a greenhouse gas impact of 5.64 kg CO_2 e/ $m^2$for a product with a mass of 1.93875 kg/m^2, giving an impact per kg of 2.9 kg CO_2 e. This compares to the figure calculated here of 2.63 kg/m^2, 10% less. Hammond & Jones (2011) provide a higher figure of 3.19 kg CO_2 e/kg for calendered sheet PVC.
Consistency e.g. with EN 15804	See www.econinvent.org.

Product code	**Product name**
	Membrane, synthetic rubber (EPDM)
Description	Based on a synthetic rubber of ethylene propylene diene monomer used as a waterproofing membrane.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Based on "Market for synthetic rubber" and "Extrusion production, plastic film".
Age	Various – see www.ecoinvent.org
Technology coverage	Only covers production of synthetic rubber and extrusion (based on data for plastic film production).
Geographical coverage	Global
Assumptions	EPDM rubber systems used in New Zealand are primarily manufactured in the USA. Data not tailored to manufacture in this location.
Completeness/ exclusions	See Technology coverage. Packaging and any ancillary materials not included.
Plausibility check	Hammond & Jones (2011) provide a greenhouse gas impact for general rubber of 2.85 kg CO_2 eq./kg, acknowledging that data are poor and indications are that synthetic rubber shows higher values. This work calculates a value of 3.6 kg CO_2 eq./kg.
Consistency e.g. with EN 15804	See www.ecoinvent.org

D1.6 Metals and metal-containing composites

Product code	Product name
	Aluminium (anodised finish, one side 0.02 mm), extruded glazing frame, 2.0 mm BMT **Aluminium (anodised finish, one side 0.02 mm), flat sheet, 0.7 mm BMT** **Aluminium (anodised finish, one side 0.02 mm), flat sheet, 0.9 mm BMT** **Aluminium (anodised, one side 0.02 mm), profile sheet metal, generic all profiles, 0.7 mm BMT** **Aluminium (anodised, one side 0.02 mm), profile sheet metal, generic all profiles, 0.9 mm BMT** **Aluminium (anodised finish, one side 0.02 mm), louvre blades, 2.0 mm BMT** **Aluminium (powder coated finish, one side 0.08 mm), extruded glazing frame, 2.0 mm BMT** **Aluminium (powder coated finish, one side 0.08 mm), flat sheet, 0.7 mm BMT** **Aluminium (powder coated finish, one side 0.08 mm), flat sheet, 0.9 mm BMT**
Description	Aluminium produced in New Zealand from primary resources is based on bauxite mined and refined into alumina in Australia, which is then shipped to Tiwai Point in the South Island. Once cast at Tiwai Point, the ingots are transported for further processing including extruding, cold rolling, anodising and powder coating.
Platform/source(s) of data	EcoInvent 3.1 – adapted to include New Zealand Grid electricity. Based on World Aluminium (2013).
Data characteristics	The aluminium model includes mining of bauxite and production of alumina in Australia, shipping to New Zealand, electrolysis and alloying (based on 6060 alloy), casting into ingots, transport to processors (taken as a 1000 km truck journey), where the ingot is either extruded or cold rolled and may be anodised or powder coated. The alloying process is based on the following composition (%): Aluminium (98.475). Cast iron (0.2) Chromium (0.05) Copper (0.1) Magnesium (0.475) Manganese (0.1) Silicon (0.45) Zinc (0.15) Anodising based on "Anodising, aluminium sheet" from EcoInvent 3.1, updated to reflect use of New Zealand Grid electricity (medium voltage), based on Sacayon Madrigal (2016). Powder coating based on "Powder coating, aluminium sheet" in EcoInvent 3.1, updated for NZ Grid electricity (medium voltage).
Age	World Aluminium mass flows are based on 2010 data. For age of EcoInvent data – see www.ecoinvent.org
Technology coverage	Aluminium electrolysis based on the prebake process and includes production of wrought aluminium which is cast into ingots, based on the alloy composition in "Data characteristics".

	Electricity for the aluminium electrolysis process is derived from the Manapouri hydro dam under a contract with Meridian Energy. However, since the electricity is delivered via the grid, there is no current mechanism in New Zealand for exclusively purchasing renewable-derived electricity from the grid and since electricity generation at the Manapouri hydro dam contributes towards national grid average emission factors, electricity demand at Tiwai Point was modelled as being supplied by Grid average electricity (based on Sacayon Madrigal, 2016). In 2014, renewables made up 80% of New Zealand grid electricity (MBIE, 2015). Data provided with a BMT of 0.7, 0.9 and 2 mm. Aluminium results may be generated with no finish, anodised or powder coated. Anodising coating thickness is 20 um. Includes mechanical surface treatment (50% of workpieces), degreasing, pickling, anodising and sealing. Also includes waste water treatment. Powder coating based on a coating thickness of 80 um. The heat consumption is calculated based on a sheet of 2 mm thickness, but is applied to all thicknesses modelled. Includes chromatising of the aluminium sheet, powder coating, heat curing and treatment of wastewater.
Geographical coverage	Rest of the World data in EcoInvent 3.1 (outside Europe).
Assumptions	Heat consumption for powder coating of 2 mm thick aluminium is assumed to be the same for 0.7 mm and 0.9 mm BMT.
Completeness/ exclusions	See www.ecoinvent.org
Plausibility check	Greenhouse gas impact calculated as 10.5 kg CO_2 eq./kg and total primary energy of 142 MJ for a flat sheet (BMT = 2 mm) with no finish up to 11.1 kg CO_2 eq./kg for an anodised or powder coated flat sheet and a total primary energy of 149 MJ. This compares with 11.1 kg CO_2 eq./kg published by the GDA (2013a, b) with a power mix for aluminium production that is largely renewables (as is the case in NZ). Total primary energy is higher at 190 MJ for coil-coated aluminium sheet (GDA, 2013a) and 202 MJ for cold formed aluminium sheet (GDA, 2013b). Other EPDs, for example, Fresia Aluminio (2014) show lower values but include secondary aluminium. EcoInvent data show a large variation in greenhouse gas impacts associated with aluminium production, due primarily to the underlying source(s) of energy supplying the electricity to the process. Where electricity is primarily coal derived, greenhouse gas impacts of aluminium production can be significantly higher. Alcorn's original work (2010) shows results that are higher, from 14.2 kg CO_2 /kg for primary aluminium up to 16.35 kg CO_2 /kg for extruded, anodised aluminium. Hammond & Jones (2011) provide values of 12.5 kg CO_2 eq./kg for extruded aluminium and 12.8 kg CO_2 eq/kg for rolled aluminium, providing similar values and showing little difference between extruded and rolled outputs (less than 3%).
Consistency e.g. with EN 15804	See www.ecoinvent.org

Product code	Product name
	Aluminium composite material (ACM) panel, 4 mm thick
Description	Thin sandwich panel of thermoplastic with aluminium sheet on each face, with a thickness of 4 mm.
Platform/source(s) of data	EPD for aluminium composite panels published by GDA (2013). The EPD represents five products weighted by production volumes of two member companies of the GDA.
Data characteristics	Data reported per m^2 and converted to "per kg" using a reported kg/m^2 rate of 7.04.
Age	Data collected in 2011 and 2012.
Technology coverage	Represents European manufacture where production technologies are reported as being comparable. For information about production, see GDA (2013).
Geographical coverage	Europe. Composite aluminium panels are largely imported into New Zealand.
Assumptions	Manufacture by reporting GDA members, and resulting impacts, are indicative of aluminium composite panel manufacture in countries importing product to New Zealand.
Completeness/ exclusions	See GDA (2013)
Plausibility check	Comparison with an Alucoil EPD (2014) for two aluminium composite panel products shows the following differences (with GDA 2013 as a baseline): Greenhouse gas: -4.6 to 45% (likely to be heavily influenced by the source of aluminium). Air acidification: within range (0.02 – 0.03 kg SO_2 eq./kg). Resource depletion (fossil fuels): within range (58 – 93 MJ/kg).
Consistency e.g. with EN 15804	EPD is compliant with EN 15804 and has been independently verified.

Product code	Product name
	Steel, structural, columns and beams
Description	Manufacture of welded beams and columns at the BlueScope Welded Products Plant at Unanderra, New South Wales, Australia from steel made at Port Kembla, Australia. Covers product in the range 350 WC to 1200 WB comprising standard steel grades G300 and G400 with L15 variants. Plate thickness is 10 – 40 mm. Does not cover specialised highly alloyed grades (from BlueScope (2015)).
Platform/source(s) of data	BlueScope (2015)
Data characteristics	Specific EPD for welded beams and columns.
Age	EPD published in 2015 based on data collected 2012 – 2014.
Technology coverage	Production of steel is by an integrated blast furnace/basic oxygen steelmaking and continuous slab casting, then hot rolling into steel plate. The plate is transported to the Welded Products Plant where it is cut and welded into beams and columns. Product contains 8.5% post-consumer recycled content, and 6.5% pre-consumer recycled content. Variation in declared indicators between standard steel grades is insignificant.

	For typical composition, see BlueScope (2015)
Geographical coverage	Australia. Welded beams are also produced in New Zealand from steel plate derived from a unique process that uses iron-rich sands (titanomagnetite) rather than iron ore as a raw material input (Jaques, 2002). No recent data are available for product derived from this process.
Assumptions	See BlueScope (2015)
Completeness/ exclusions	See BlueScope (2015)
Plausibility check	The value of indicators is significantly influenced by the underlying process for manufacturing the steel and the amount of recycled content in the steel product. Hammond & Jones (2011) report 2.31 kg CO_2 eq./kg for steel plate with a 35.5% recycled content for the "Rest of the World" (outside Europe), compared to 2.85 kg CO_2 eq./kg from the BlueScope EPD (with a recycled content of 15%). The theoretical greenhouse gas impact for steel plate with no recycled content is 3.27 kg CO_2 eq./kg, excluding cutting of the steel plate. The embodied energy range is 33 MJ/kg (35.5% recycled content) to 45 MJ/kg (hypothetical virgin product) compared to 31.9 MJ/kg from BlueScope. Data produced from Nebel, Alcorn and Wittstock (2011) provides a carbon dioxide emission of 2.1 kg/kg steel. No information provided on source of data, recycled content etc. Data reported as from 2006. Worldsteel data for steel plate (blast furnace route) collected using Worldsteel methodology in 2007 shows values that are lower eg. global warming impact of 2.35 kg CO_2 eq./kg, except for net water consumption and waste, for which figures reported in BlueScope (2015) are lower. Jaques (2002) shows 1998 carbon dioxide emissions (only) of 2.45 kg/kg finished plate for production at the NZ plant (excluding production of finished beam from the plate). With expected gains in efficiency since 1998, the figures used here may be conservative for NZ made product. Lack of available data does not allow this to be substantiated.
Consistency e.g. with EN 15804	The EPD was developed in compliance with EN 15804.

Product code	Product name
	Stud wall system, steel (galvanised finish, two sides, 0.02 mm each), 92.1x33.1 0.55 BMT @ 300ctrs, wall height 4.4-8.8 m, 1 nogging row **Stud wall system, steel (galvanised finish, two sides, 0.02 mm each), 92.1x33.1 0.55 BMT @ 450ctrs, wall height 4.4-8.8 m, 1 nogging row** **Stud wall system, steel (galvanised finish, both sides, 0.02 mm each), 150x33.1 0.75 BMT @ 800ctrs, wall height 4.4-8.8 m, 1 nogging row** **Steel (galvanised finish, both sides, 0.02 mm each), profile metal sheet, generic all profiles, 0.4 mm BMT**
Description	The zinc coating on galvanised steel provides a cathodic protection. Used as wall and roof framing and as a supporting tray for upper floor

	structures. Relevant to profiles manufactured from cold-formed galvanized steel sheets between 0.6 – 3.0 mm.
Platform/source(s) of data	Based on data for light gauge steel profiles in an EPD by Akkon Steel Structure Systems Co (2012).
Data characteristics	Based on EPD data compliant with EN 15804.
Age	Data collected in 2011.
Technology coverage	Based on primary steel production to produce a hot dipped zinc coated steel.
Geographical coverage	EPD is for an operation in Turkey.
Assumptions	Operations at the plant are representative of operations supplying galvanised steel profiles to New Zealand. The zinc coating is 0.02 mm on both sides = 0.04 mm in total. Using a zinc density of 7130 kg/m^3, this gives a zinc mass of 0.285 kg/m^2 steel, which is close to the stated zinc coating of 275 g/m^2 in the Steel & Tube Purlins & Girts Catalogue, therefore reasonable.
Completeness/ exclusions	EPD complies with the completeness requirements in EN 15804.
Plausibility check	Several EPDs have been published for galvanised steel profiles including: IFBS (2013) for thin walled profiled sheets used as a wall and roof covering and as a tray in single or double layer roof, wall and ceiling structures. This represents results of 12 member companies producing profiles of 0.75 mm thickness, which additionally includes an organic coating. European Association for Panels and Profiles (2013) for thin walled profiled sheets used as a wall and roof covering and as a tray in single or double layer roof, wall and ceiling structures. This represents results of 11 member companies producing profiles of 0.75 mm thickness, which additionally includes an organic coating. Europrofil (2014) for light gauge steel profiles produced in Scandinavia. MAF (2014), based on data developed by Alcorn (2010). Greenhouse gas impact of 2.62 kg CO_2 eq./kg used in this work compares to these as follows: 2.4 kg CO_2 eq./kg. 2.4 kg CO_2 eq./kg. 2.54 kg CO_2 eq./kg (for steel 2c in the EPD). 2.28 kg CO_2 eq./kg. The MAF data were not used due to difficulty in calculating associated module D benefits from recycling.
Consistency e.g. with EN 15804	The EPD is consistent with EN 15804.

Product code	Product name
	Steel (150g/m² zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, 0.4 mm BMT **Steel (150 g/m² zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, 0.55 mm BMT** **Steel (150 g/m² zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, 1.2 mm BMT**
Description	Steel with an alloy coating consisting of primarily zinc and aluminium with a mass of 150 g/m²covering both sheet surfaces.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Includes "steel finished cold rolled coil", "zinc coating, coils", "aluminium production, primary, liquid, prebake" and "silicon production, metallurgical grade"
Age	Various – see www.ecoinvent.org
Technology coverage	Based on primary steel production with a 150 g/m² coating of zinc (44%), aluminium (55%) and silicon (1%). Data show a steel scrap input of 9.5%.
Geographical coverage	Rest of the World (RoW) data in EcoInvent 3.1 and Global data.
Assumptions	No data could be found for steel profile with a zinc – aluminium alloy coating, therefore these data are an approximation only.
Completeness/ exclusions	Data used to represent the alloying process missing.
Plausibility check	Alcorn (2010) reports an embodied carbon figure of 8.06 kg CO_2 eq./m² for 0.4 mm thick steel roofing with a zinc/aluminium coating. This equates to 3.12 kg steel (using an assumed density of 7800 kg/m³) giving a greenhouse gas impact per kg steel of 2.58. This compares with 2.75 kg CO_2 eq./kg calculated for this work (a 6% difference).
Consistency e.g. with EN 15804	No information.

Product code	Product name
	Steel (150 g/m² zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, factory paint finish both sides, 0.4 mm BMT **Steel (200g/m² zinc/aluminium alloy finish both sides), profile metal sheet, generic all profiles, factory paint finish both sides, 0.4 mm BMT**
Description	Steel with an alloy coating consisting of primarily zinc and aluminium with a mass of 150 g/m² or 200 g/m² covering both sheet surfaces and a factory applied paint finish to both sides.
Platform/source(s) of data	EcoInvent 3.1
Data characteristics	Includes "steel organic coated", "zinc coating, coils", "aluminium production, primary, liquid, prebake".
Age	Various – see www.ecoinvent.org
Technology coverage	Based on primary steel production of steel including pickling and cold rolling. An alloy coating of 150 g/m² or 200 g/m2 zinc (45%) and aluminium (55%) is applied plus oven cured organic coating to provide colour and corrosion resistance. Data show a steel scrap input of 7.14%.

Geographical coverage	Rest of the World (RoW) data in EcoInvent 3.1 and Global data.
Assumptions	No data could be found for steel profile with a zinc – aluminium alloy and organic coating, therefore these data are an approximation only.
Completeness/ exclusions	Data used to represent the alloying process missing.
Plausibility check	Alcorn (2010) reports an embodied carbon figure of 8.785 kg CO_2 eq./m^2 for 0.4 mm factory painted steel roofing and 10.6 kg CO_2 eq./m^2 for 0.55 mm factory painted steel roofing. This equates to 3.12 kg and 4.29 kg of steel roofing respectively (using an assumed density of 7800 kg/m^3), and produces a greenhouse gas impact of between 2.5 – 2.8 kg CO_2 eq./kg. By comparison, this work calculates a greenhouse gas impact of 3.27 kg CO_2 eq./kg (for 150 g/m^2 alloy coating) and 3.41 kg CO_2 eq./kg (for 200 g/m^2 alloy coating), a 19 - 24% difference.
Consistency e.g. with EN 15804	No information.

D1.7 Paint

Product code	**Product name**
	Paint, water-borne, exterior **Paint, water-borne, exterior masonry** **Paint, water-borne, primer/sealer**
Description	Paints have traditionally been solvent-based but water-based formulations are more common in order to reduce emission of volatile organic compounds (VOCs). Waterborne paints include acrylics and co-polymers.
Platform/source(s) of data	AkzoNobel EPD (2014) and Nebel, Alcorn and Wittstock (2011).
Data characteristics	Indicators are provided per m^2 for one layer. Most environmental indicators, water and waste taken from AkzoNobel (2014), adapted to represent values for one layer. Resource depletion and total primary energy calculated based on reporting of "Paint - resources" in EPD. Stratospheric ozone depletion indicator taken from Nebel, Alcorn and Wittstock (2011), adjusted for mass per m^2, as this is not reported in the EPD. The following paints were selected from AkzoNobel (2014): Undercoat – quick dry exterior undercoat pure brilliant white. Weight per layer = 0.083 kg/m^2. Water-based formulation. Exterior Satin – quick dry exterior satin pure brilliant white. Weight per layer = 0.064 kg/m^2. Water-based formulation and contains a fungicide to inhibit mould growth. Masonry – smooth masonry paint pure brilliant white. Weight per layer = 0.136 kg/m^2. Based on an acrylic resin and contains a fungicide for inhibit mould growth.
Age	AkzoNobel EPD published in 2014. Nebel, Alcorn and Wittstock (2011) based on work by Alcorn published in 2010.
Technology coverage	According to AkzoNobel (2014), pigment is dispersed in a binder and solvent. Tinter added to correct colour and the paint is thinned to the required viscosity, filtered and filled into a packaging container.
Geographical coverage	AkzoNobel (2014) based on production at three sites in the UK. These data are used in the absence of New Zealand specific data.

Assumptions	Production in the UK, and the impacts associated with this, are similar in New Zealand.
Completeness/ exclusions	Stratospheric ozone depletion impacts are not reported in AkzoNobel (2014), so figures for this indicator are based on MAF (2014). There is likely to be differences in the underlying basis of both studies.
Plausibility check	Hammond & Jones (2011) report greenhouse gas emissions for waterborne paint of 0.44 kg CO_2 eq. /m^2, with a total primary energy of 10.5 MJ/m^2, based on a coverage of 0.15 kg/m^2. They report that embodied carbon figures for paint show a particularly high range in the literature. Figures used in this work for waterborne paints are 0.2135 kg CO_2 eq./m^2 for exterior satin paint with a coverage of 0.064 kg/m^2. Adjusting for coverage, provides a figure of 0.5 kg CO_2 eq./m^2, 14% higher than the Hammond & Jones figure. Alcorn (2010) reports 1.64 kg CO_2 eq./kg for water based paint. This compares to 2.8 kg CO_2 eq./kg from data produced for Nebel, Alcorn and Wittstock (2011) for water based paint. Applying the coverage rate of 0.064 kg/m^2 used for this work, the Nebel, Alcorn and Wittstock (2011) greenhouse gas impact equates to 0.18 kg CO_2 eq./m^2, about 19% less.
Consistency e.g. with EN 15804	EPD produced in accordance with ISO 14025

D1.8 Plasterboard

Product code	**Product name**
	Gypsum plasterboard
Description	Gypsum plasterboard comes as sheets consisting of gypsum plaster with fillers and paper linings. They can be produced for specific applications, for example, wet areas.
Platform/source(s) of data	Based on data derived from Nebel, Alcorn and Wittstock (2011)
Data characteristics	Aggregated data set.
Age	2005
Technology coverage	Covers all relevant process steps/technologies over the supply chain of the represented cradle to gate inventory with a good overall data quality. The inventory is mainly based on industry data and is completed, where necessary, by secondary data.
Geographical coverage	New Zealand
Assumptions	No information provided.
Completeness/ exclusions	No information provided.
Plausibility check	Results compared to other data sources, specifically: ICE database (Hammond & Jones; 2011). Alcorn (2010). EcoInvent 3.1 Good agreement with ICE database (0.39 kg CO_2 eq./kg compared to 0.32 kg CO_2 eq./kg in this work) and EcoInvent 3.1. Alcorn (2010) has a higher figure of 0.47 kg CO_2 /kg.

Consistency e.g. with EN 15804	No information provided.

D1.9 Renewable energy infrastructure (on site)

Product code	Product name
	Energy generation, photovoltaic (PV) system (incl. roof mounts), 3kWp
Description	Photovoltaic panels convert solar energy into DC electricity, which is converted to AC electricity by an inverter.
Platform/source(s) of data	EcoInvent 3.1; Fraunhofer Institute for Solar Energy Systems, 2016; IPCC, 2012
Data characteristics	Indicators are provided for a complete 3 kWp photovoltaic system using EcoInvent data. The greenhouse gas impact is calculated using a market split between multi-crystalline and mono-crystalline PV (excluding thin film) from Fraunhofer (2016) and greenhouse gas impact for the two types of PV cited in IPCC (2012 [pg 67]), with greenhouse gas emissions from the flat roof mounting system added from EcoInvent data. EcoInvent are global data including market for photovoltaic mounting system, for flat roof installation, market for photovoltaic flat roof installation, 3 kWp, single-Si, on roof and market for photovoltaic flat roof installation, 3 kWp, multi-Si, on roof.
Age	See www.ecoinvent.org
Technology coverage	Production of mono-crystalline and poly-crystalline photovoltaic panels, plus flat roof mounting system.
Geographical coverage	Global data since panels are imported to New Zealand.
Assumptions	New Zealand market taken as 74.4% polycrystalline PV and 25.6% monocrystalline PV (based on Fraunhofer, 2016). Based on a 250 W panel area occupying an area of 1.58 m^2 (i.e. 0.99 m x 1.6 m), 12 panels needed for a 3 kWp system, which equates to 19 m^2 with a mass of 228 kg (panels only).
Completeness/ exclusions	Packaging and fixing materials excluded.
Plausibility check	Alcorn (2010) provides an embodied carbon figure of 235 kg/m^2. In this work, a 3 kWp system has a greenhouse gas impact of 7225 kg CO_2 eq, which equates to 380 kg CO_2 eq./m^2 (with mounting) and 333 kg CO_2 eq./m^2 (without mounting). Moore cites a 1 kW PV solar system creates "just over 2 tonnes of greenhouse gases", with 85% of this coming from manufacture of the PV modules. The model in this work produces a figure of 2.1 tonnes greenhouse gases for the PV modules only.
Consistency e.g. with EN 15804	See www.econinvent.org

D1.10 Timber and engineered wood

Product code	Product name
	Engineered wood, cross laminated timber (CLT)
Description	An engineered wood product consisting of layers of softwood laminates glued perpendicular to each other to form a structural product.

Platform/source(s) of data	Wood for Good (www.woodforgood.com)
Data characteristics	Data provided on a per cubic metre basis and converted to a per kg basis using a product density of 488 kg/m^3. 12% moisture content.
Age	Reference year is 2013.
Technology coverage	Manufacture involves logging, sawing and kiln drying, followed by finger jointing of softwood timber pieces to form long laminates which are glued together perpendicular to neighbouring layers and pressed. The grain of each laminate is oriented at right angles to the neighbouring laminate. The grain of outer layers is oriented along the length.
Geographical coverage	Data represent production for the UK market, primarily coming from Europe – 74% of imports are from countries with low carbon (renewables, nuclear) supplying Grid electricity.
Assumptions	Production of LVL in Europe, and the impacts associated with it, are similar to New Zealand production. The Wood for Good data are based on a five layer product made from kiln dried softwood. Actual product may be 3, 5 or 7 layers.
Completeness/ exclusions	Timber treatment (if needed). Data are provided as a guide in the absence of locally representative data.
Plausibility check	Results presented in BS Holz (2015a) show a 21% higher greenhouse gas saving and slightly lower total primary energy (5%). Net freshwater and total waste results show large differences. The Wood for Good figures may therefore be considered as conservative.
Consistency e.g. with EN 15804	Underlying data are consistent with EN 15804. However, data are not geographically representative.

Product code	**Product name**
	Engineered wood, glued laminated timber (Glulam)
Description	An engineered wood product consisting of laminations (planks) glued together in parallel to form a higher load bearing structure.
Platform/source(s) of data	Wood for Good (www.woodforgood.com)
Data characteristics	Data provided on a per cubic metre basis and converted to a per kg basis using a product density of 490 kg/m^3. 12% moisture content.
Age	Reference year is 2013.
Technology coverage	Manufacture involves logging, sawing and kiln drying, followed by finger jointing of softwood timber pieces to form long laminates which are glued together and pressed. The grain is oriented along the length.
Geographical coverage	Data represent production for the UK market, primarily coming from Europe – 55% of imports are from countries with low carbon (renewables, nuclear) supplying Grid electricity.
Assumptions	Production of LVL in Europe, and the impacts associated with it, are similar to New Zealand production.
Completeness/ exclusions	Timber treatment (if needed). Data are provided as a guide in the absence of locally representative data.
Plausibility check	Figures found vary considerably for greenhouse gas impacts associated with glulam manufacture.

	Alcorn (2010) reports a figure of -1.36 kg CO_2 eq./kg whereas the EPD from BS Holz (2013b) shows -1.27 kg CO_2 eq./kg. The American Wood Council and Canadian Wood Council published an EPD for glulam in 2013c, based on ISO 21930. This reports greenhouse gas emissions in production, without inclusion of carbon dioxide taken up by the growing tree. A cubic metre has a stated oven dry mass of 533.97 kg. At 50% carbon content, this equates to 533.97 * 50% * (44/12) = 978.9 kg CO_2/m^3 LVL. 197.97 (greenhouse gas impact in EPD) – 978.9 = - 780.93 kg CO_2/m^3. Dividing by the dry mass/m^3 = -780.93/533.97 = -1.46 kg CO_2 eq./kg These compare to a greenhouse gas saving of -1 kg CO_2 eq./kg used here, based on Wood for Good. This is therefore a more conservative figure.
Consistency e.g. with EN 15804	Underlying data are consistent with EN 15804. However, data are not geographically representative.

Product code	**Product name**
	Engineered wood, I-joist profile, 200x45 **Engineered wood, I-joist profile, 300x63** **Engineered wood, I-joist profile, 300x90** **Engineered wood, I-joist profile, 360x90** **Engineered wood, I-joist profile, 200x45** **Engineered wood, I-joist profile, 240x46** **Engineered wood, I-joist profile, 240x90** **Engineered wood, I-joist profile, 360x63** **Engineered wood, I-joist profile, 400x90**
Description	These engineered wood I joists consist of structural laminated veneer lumber (LVL) flanges with a structural plywood web. They may be treated or untreated.
Platform/source(s) of data	FWPA (2015) for plywood and Wood for Good (www.woodforgood.com) for LVL.
Data characteristics	See *Engineered wood, laminated veneer lumber (LVL)* and *Plywood*
Age	See *Engineered wood, laminated veneer lumber (LVL)* and *Plywood*
Technology coverage	See *Engineered wood, laminated veneer lumber (LVL)* and *Plywood*
Geographical coverage	See *Engineered wood, laminated veneer lumber (LVL)* and *Plywood*
Assumptions	The ratio of LVL to plywood varies with the size of the I-joist but is in the range 64 – 69% LVL, with the remainder being plywood.
Completeness/ exclusions	Includes logging, sawing and kiln drying before production of LVL and plywood. A limitation of these data is that they only comprise the production of LVL and plywood separately. Fabrication into the I beam is excluded due to lack of data. Therefore, the data may be considered as under-representing the impacts of manufacture. Timber treatment is also excluded (if needed). Data are provided as a guide but are likely to under-report impacts.

Plausibility check	The American Wood Council and Canadian Wood Council (2013a) have published an EPD compliant with ISO 21930 (rather than EN 15804) for North American production of wood I joists. The EPD reports a 10 m length I-joist as having a mass of 36.44 kg (oven dry). Assuming 50% is carbon, this equates to carbon dioxide take up of 36.44 * 50% * (44/12) = -66.8 kg The stated greenhouse gas emission figure in the EPD is 16.74 kg CO_2 eq., excluding carbon dioxide absorption. 16.74 – 66.8 = -50.06 kg CO_2 eq. net. -50.06/36.44 = -1.37 kg CO_2 eq./kg (taking into account take up of carbon dioxide by the growing trees making up the product). This compares to a calculated figure of -0.92 kg CO_2 e used here. The lower figure is primarily due to use of the FWPA plywood figure, which shows a low net carbon dioxide take up (-0.54 kg CO_2 eq).
Consistency e.g. with EN 15804	Underlying data for LVL and plywood are consistent with EN 15804.

Product code	**Product name**
	Engineered wood, laminated veneer lumber (LVL)
Description	An engineered wood product consisting of veneers pressed together with phenol formaldehyde resin.
Platform/source(s) of data	Wood for Good (www.woodforgood.com)
Data characteristics	Data provided on a per cubic metre basis and converted to a per kg basis using a product density of 488 kg/m^3. 12% moisture content.
Age	Reference year is 2013.
Technology coverage	Manufacture involves logging, sawing, kiln drying, followed by production of veneers from the softwood logs, drying and then pressing together veneers (with the grain oriented along the length) with resin, followed by trimming to required dimensions.
Geographical coverage	Data represent production for the UK market, primarily coming from Europe – 80% of imports are from countries with low carbon (renewables, nuclear) supplying Grid electricity.
Assumptions	Production of LVL in Europe, and the impacts associated with it, are similar to New Zealand production.
Completeness/ exclusions	Timber treatment (if needed). Data are provided as a guide in the absence of locally representative data.
Plausibility check	A carbon footprint report prepared by Scion for New Zealand LVL (Love, 2010) provides a carbon footprint for untreated LVL of -720.75 kg CO_2 eq./m^3 LVL and for treated LVL of -611.42 kg CO_2 eq./m^3. The American Wood Council and Canadian Wood Council published an EPD for LVL in 2013b, based on ISO 21930. This reports greenhouse gas emissions in production, without inclusion of carbon dioxide taken up by the growing tree. A cubic metre has a stated oven dry mass of 545.87 kg. At 50% carbon content, this equates to 545.87 * 50% * (44/12) = 1000.76 kg CO_2/m^3 LVL. 201.8 (greenhouse gas impact in EPD) – 1000.76 = -798.96 kg CO_2/m^3. Dividing by the dry mass/m^3 = -798.96/545.87 = -1.46 kg CO_2 eq./kg The Wood for Good figure of -1.1 kg CO_2 eq./kg is conservative by comparison.

Consistency e.g. with EN 15804	Underlying data are consistent with EN 15804. However, data are not geographically representative.

Product code	Product name
	Engineered wood, plywood
Description	From FWPA (2015a) "plywood is a panel product made of thin veneers of wood peeled from softwood and hardwood logs and bonded by resin. Plywood product are either engineered wood panels (such as structural plywood and formwork plywood) or non-structural panels (such as interior and exterior plywood)".
Platform/source(s) of data	FWPA (2015a)
Data characteristics	EPD – figures used for exterior plywood, A-bond, 9 mm (structural). Sector average data (90% of Australian plywood manufacture).
Age	EPD published in 2015. Wood input data from CSIRO (2009).
Technology coverage	The EPD covers six plywood products from which indicators for exterior plywood, A bond, 9 mm (structural) are used. This has a mass per m^2 of 5.42 and a density of 602 kg/m^3. Includes an Australian industry average of total preservative use across all plywood product types.
Geographical coverage	Australia. Used in the absence of recent publically available New Zealand data.
Assumptions	See FWPA (2015a). In using these data, the assumption is that New Zealand production of plywood would yield similar environmental impacts.
Completeness/ exclusions	See FWPA (2015a).
Plausibility check	Results compared to other data sources, specifically: ICE database (Hammond & Jones; 2011). Wood for Good Lifecycle database (www.woodforgood.com) where figures "per m^3" have been adjusted on a "per kg" basis, using a stated density of 491 kg/m^3 for plywood. Greenhouse gas results appear to vary across information sources. ICE figures show fossil carbon dioxide of 0.45 kg CO_2 eq/kg and biomass carbon dioxide of 0.65 kg CO_2 eq/kg, providing an A1–A3 impact of -0.2 kg CO_2 eq/kg. Wood for Good greenhouse gas figure is -1.39 kg CO_2 eq/kg (5% moisture), for a less dense product (491 kg/m^3 compared to 602 kg/m^3 from FWPA (2015)). This compares to -0.54 kg CO_2 eq/kg calculated from FWPA (2015a).
Consistency e.g. with EN 15804	EPD prepared consistent with EN 15804.

Product code	Product name
	Post tensioned timber frame structure, laminated veneer lumber (LVL), inc. steel reinforcing
Description	An engineered wood product consisting of veneers pressed together with phenol formaldehyde resin, prestressed with steel rod.
Platform/source(s) of data	Wood for Good (www.woodforgood.com) for LVL, EcoInvent 3.1 for steel.

Data characteristics	Based on drawings for a New Zealand building that uses a hybrid LVL structural system, the proportion of steel by mass is 4.45% with the remainder being LVL. For LVL, see **Engineered Wood, Laminated Veneer Lumber (LVL)** Steel rod data is based on steel reinforcing data calculated using EcoInvent 3.1, adapted with New Zealand Grid electricity (from Sacayon Madrigal, 2016). Manufacture based on a primary route.
Age	Reference year is 2013 for LVL data.
Technology coverage	For LVL, see **Engineered Wood, Laminated Veneer Lumber (LVL)** Steel rod data based on production using a blast furnace.
Geographical coverage	For LVL, see **Engineered Wood, Laminated Veneer Lumber (LVL)** Steel rod production data based in "Rest of the World" data in EcoInvent 3.1, adapted to include use of New Zealand Grid electricity.
Assumptions	The hybrid LVL system is prefabricated in Christchurch. This provides the basis for calculating transport distances. It is assumed that the prefabrication process produces 0.5% steel waste and 2.5% LVL waste by mass (these values being half the waste of structural steel and LVL at construction sites in the module A5 datasheet). The lower wastage rates are applied assuming that a controlled factory environment provides an easier environment for reducing and managing waste. All waste steel is assumed to be recycled and all waste LVL is assumed to be landfilled. For LVL, see **Engineered Wood, Laminated Veneer Lumber (LVL)**
Completeness/ exclusions	The data include production of LVL and steel rod and their transport to Christchurch, where it is assumed that the hybrid LVL system is prefabricated. Transport distances are based on the module A4 datasheet. No data are available for the manufacture of the hybrid LVL system, including what energy and consumables are required and what wastes are produced. Timber treatment is also excluded (if needed). Data are provided as a guide and are likely to under-report indicators.
Plausibility check	No data have been found for comparison.
Consistency e.g. with EN 15804	Underlying LVL data are consistent with EN 15804 but not geographically representative. Data gaps exist including manufacture of the prefabricated system.

Product code	**Product name**
	Timber, soft wood, sawn kiln-dried sections
Description	Sawn, kiln dried softwood is used as structural framing.
Platform/source(s) of data	FWPA (2015b)
Data characteristics	Sector average EPD for Australian production of softwood timber with a density of 559 kg/m^3, 12% moisture content (dry basis).
Age	EPD published in 2015. Wood input data from CSIRO (2009).
Technology coverage	Includes forestry operations, sawing and drying of softwood timber.
Geographical coverage	Australia. Used in the absence of recent NZ data.

Assumptions	See FWPA (2015b). Dominant softwood species is radiata pine (*Pinus radiata*). Other softwood species used include hoop pine (*Araucaria cunninghami*) and maritime pine (*Pinus pinaster*). In using these data, the assumption is that New Zealand production would yield similar environmental impacts.
Completeness/ exclusions	Timber treatment and any packaging used.
Plausibility check	Alcorn (2010) provides a value of -1.32 kg CO_2 eq./kg for kiln dried, dressed and treated timber. Wood for Good (www.woodforgood.com) has a value of -1.41 kg CO_2 eq./kg for kiln dried sawn softwood. The FWPA (2015b) figure used here is -1.25 kg CO_2 eq./kg, showing reasonable agreement (maximum of 11% difference)
Consistency e.g. with EN 15804	EPD prepared consistent with EN 15804.

D2. Construction process stage (modules A4–A5)

Indicators are calculated per kg of product incorporated into the building (which may be obtained from an output from a BIM model or by applying square metre rates).

Generic transport distances from the last manufacturing, fabrication or assembly process (in the Product Stage) to a construction site in either Auckland, Wellington or Christchurch CBD are provided in the module A4 datasheet. The basis for derivation of these transport distances is provided in the BRANZ SR351 study report (Dowdell et al., 2016). All transport is modelled on a tonne.km basis as one way loaded journeys only. This is primarily due to the lack of parameterisation in available transport data in EcoInvent 3.1 making it difficult to account for empty return journeys[19]. Also, there is a lack of generic utilisation data by product available.

Packaging of construction products, including use of pallets, is not considered. Therefore, manufacture of the packaging and its subsequent end of life are not included. Similarly, ancillary materials e.g. required for fixing such as nails, screws, bolts, and release agent for concrete, are not included. Use of power tools is also not included.

Where data includes use of diesel on a construction site, the EcoInvent 3.1 data "diesel, burned in building machine" are used, adapted to reflect a 10 ppm sulphur content i.e. 4 E^{-7} kg sulphur dioxide per MJ, from:

1 MJ diesel = 1/43 kg = 0.023 kg diesel

4 E^{-7} kg SO_2 * (16/32) = 2 E^{-7} kg S

2 E^{-7} kg S/0.023 kg diesel = <10 ppm S

Where products are lifted, for example from a delivery truck, an empirical formula provided by The Athena Sustainable Materials Institute (2015) is used as a basis for calculating the energy required. A lift height of 6 m using diesel as a source of fuel, gives an energy figure of 0.151 MJ/kg lifted (6 m). This is applied universally on the

[19] Through communication with The EcoInvent Centre, it is understood that parameterised truck transport data is likely to be developed in the future.

basis that energy required for lifting materials is not significant across the building life cycle.

Material and product waste generated at the construction site is based on the module A5 datasheet, which also sets out the fate of any generated waste. For example, for a product for which 5% is waste during construction, module A4-A5 accounts for transport of 1.05 kg of the product for every 1 kg that is incorporated in the building.

The manufacture of the additional 0.05 kg required that becomes waste (per kg incorporated in the building) is also accounted in module A4-A5, based on environmental indicators calculated for module A1–A3.

For waste going to landfill, a distance of 20 km is assumed. For waste that requires further transport and/or processing before reaching the "end of waste state", this is included in module A4-A5.

Specific information about materials and products, where relevant, is provided below. Where no specific information is provided, the approach set out in this section is applied.

D2.1 Aggregates

Description	Energy required for moving based on 0.4 kg diesel /m^3. Applying a density of 2240 kg/m^3 for sand and a net heat value of 43 MJ/kg (CAENZ, 2008), provides an energy use (MJ) per kg of (0.4 * 43)/2240 = 0.0076 MJ/kg.

D2.2 Concrete and cement-containing materials

Description	**Reinforcement** Separate transport of all in-situ concrete and reinforcement (including concrete and reinforcement wasted at the construction site) is accounted in modules A4 – A5, as is onward transport and processing of the waste. **Formwork and falsework** Formwork is a temporary structure, supported by falsework, which provides a mould into which plastic concrete is poured and retained until it has cured sufficiently to support required loads. It also imparts the required surface finish (CCANZ, 2010). There are many variables concerning formwork (and falsework), including: The type of structure being constructed, for example, whether a wall, beam, column or slab. The amount of bracing required, including choice of spans between studs and centres between walers or bearers. The type of materials used, for example, plywood, metal or timber. A full list of materials that may be used as formwork is provided in CCANZ, 2010. Whether the formwork is reusable or designed for a once only use. The number of times reusable formwork may be used is dependent, in part, on appropriate storage and maintenance. Temporary formwork is not included due to this inherent variability. A report by Lemay (2011) which compared structural concrete and steel frames notes "the concrete structural frame has more associated energy use, CO_2, CO, NO_2, particulate matter smaller than 10 micrometres, SO_2 and hydrocarbon emissions due to more temporary materials, particularly formwork, larger transportation impacts due to a larger mass of materials,

	and longer equipment use due to the longer installation process". The paper goes on to conclude that when evaluating buildings over a 50 year life, "the differences noted in the construction stage disappear and the use phase dominates". This conclusion suggests that the exclusion of temporary formwork is not material at the building level and is therefore reasonable to exclude. Permanent formwork may also be used in construction, for example, in upper floor applications which use precast concrete (e.g. double tees) or galvanised steel profiles, into which ready mixed concrete is poured to provide a floor surface. Permanent formwork is considered. **Placing on site (in situ concrete)** Assumption is that 0.6 L diesel are used per cubic metre pumped, based on anecdotal data provided by Hawkins Construction Limited. Aggregate is recovered from some wet concrete left over from the construction site. The amount is set out in the module A5 datasheet. Washing of concrete to recover aggregate is additional to A1–A3 impacts, as the data do not cover this activity. Water use to recover aggregate is based on CCANZ (2011) assuming a truck makes 4 trips in a day, each carrying 7 m^3 of concrete. Reinforcement is collected and most transported for recycling which occurs overseas. **Placing on site (plaster and grout)** Assume 1 part water is added to 6 parts dry plaster at the construction site, based on NZS4251.1 (Appendix C, C2). Transport of plaster to the construction site is therefore based on a mass of 0.86 kg per kg used in the build, multiplied by the waste factor from the module A5 datasheet. Tap water is used, the supply of which is represented by the EcoInvent 3.1 dataset "tap water production, conventional treatment". Mixing of plaster is based on the EcoInvent 3.1 dataset "plaster mixing" adapted to include NZ Grid electricity (Sacayon Madrigal, 2016). Since data for production of grout is based on in situ concrete data, it is assumed brought to site wet.

D2.3 Glass

Description	Module A4 transport may be based on 4211 Proprietary Curtain Walling and 4611 Exterior Glazing, both of which show different transport distances according to the module A4 datasheet. To simplify modelling of reference buildings, all modelling of glass is based on distances provided for 4611 Exterior Glazing, even if used as part of a curtain wall.

D2.4 Insulation

Description	Given the bulky nature of insulation products, calculation of transport impacts on a tonne.km basis may slightly under-represent the impacts arising from transport, which may be volume rather than mass constrained.

D2.5 Membrane systems

Description	Fibre reinforced bitumen membranes are typically torched on. Using figures in BWA (2013), 0.4 kg of propane is required to torch on 1 m^2 of membrane. With a mass per m2 of 8.5 kg, this equates to 0.047 kg propane per kg of fibre reinforced bitumen membrane. With a net heat value of 46.3 MJ/kg for propane (CAENZ, 2008), the energy from propane required is 2.18 MJ/kg membrane. Combustion of propane is represented by the EcoInvent 3.1 data "propane, burned in building machine" and production of propane is represented by the data "propane extraction, from liquefied petroleum gas". Both data are Global.

D2.6 Metals and metal-containing composites

Description	<u>Aluminium</u> Module A4 transport distances for aluminium (from the module A4 datasheet) vary depending on application between *3612 Minor structures, 4232 Metal and metal faced sheet cladding, 4241 Metal profile sheet cladding* and *4363 Fully supported flat aluminium sheet roofing* and *4521 Aluminium windows and doors*. For the purposes of simplifying modelling of reference buildings, all transport of aluminium is based on *4521 Aluminium windows and doors* whether used in this or another application (due to the significance of aluminium use as window framing in New Zealand compared to other construction applications). Transport of aluminium composite panel is based on *4257 Metal clad insulating cladding* in the module A4 datasheet. <u>Steel</u> In the module A4 datasheet, transport of structural steels (beams, studs and structural profiles) is based on *3411 Structural steelwork.* Transport of steel profiles or sheets e.g. used as cladding, is based on *4311 Profiled metal sheet roofing.* In the module A5 datasheet, steel I beams, galvanised steel studs and trough profiles are treated as structural steel. Steel profile sheet, used as a cladding, is treated as steel (sheet). <u>End of Waste State of Metals</u> Aluminium and steel waste generated at the construction site is considered to reach its end of waste state on disposal at the construction site, due to its clean nature. No further processing or transport is considered from this point.

D2.7 Paint

Description	Indicators are taken from AkzoNobel (2014) and includes paint distribution, paint use, transport and paint and packaging end of life. These data have been used to ensure proper account of any emissions during paint use. However, this means that default transport distances from the module A4 datasheet have not been able to be used. The EPD does not appear to include manufacture of paint that becomes waste in this module. Therefore, this is added in, based on the waste rate in the module A5 datasheet. The AkzoNobel (2014) data include end of life routes for paint and containers (either polypropylene or tin cans). The designation of the waste

	paint as a hazardous or non-hazardous waste in the EPD is based on the EU Dangerous Preparations Directive (1999/45/EC).

D2.8 Plasterboard

Description	Recycling of plasterboard produced at the construction site includes crushing, processing and onward transport (assumed to be to Westport cement works from Christchurch - one way distance of 330 km). Processing of waste plasterboard is based on the EcoInvent 3.1 dataset "treatment of waste gypsum plasterboard, sorting", adapted to include use of New Zealand electricity (Sacayon Madrigal, 2016). The process results in a loss of collected product of 17%. Therefore for a kg of waste plasterboard collected for recycling, 0.85 kg of crushed gypsum is produced for secondary use. It is assumed that the crushed gypsum is used in cement production at the Westport Cement works which takes the crushed recycled gypsum for free, and therefore transport to Westport is included within the system boundary i.e. end of waste state is reached on arrival at Westport.

D2.9 Timber and engineered wood

Description	Module A4 transport is based on the module A4 datasheet, which has different transport distances for timber according to the classifications *3811 Prefabricated Timber Elements, 3812 Timber Platform, 3821 Framing, 4221 Timber Solid Cladding* and *4222 Manufactured Timber Sheet Cladding*. To simplify modelling of reference buildings, all transport of timber is based on distances for *3821 Framing*. Transport for engineered woods is based on *3813 Engineered Wood Products,* except hybrid LVL (see below). For landfilling, see information provided for module C. <u>Hybrid LVL</u> Since the assumption is that the prefabrication of the hybrid LVL structural system is in Christchurch, transport from the prefabrication plant to Auckland, Wellington and Christchurch is assumed to be by truck using distances in the Distance-Mode Model in the module A4 datasheet.

D3. Use stage (modules B2 maintenance and B4 replacement)

Maintenance (module B2) and Replacement (module B4) are modelled according to data provided in the module B2 and B4 datasheets respectively. The data in these datasheets has been compiled according to the method set out in the BRANZ SR351 study report (Dowdell et al., 2016).

Provided recommended maintenance is carried out as required by the manufacturer, the view is taken that a material or product will, in general, reach its estimated service life without the need for repair. Upon reaching its estimated service life, the material or product is replaced with a like-for-like alternative.

Repair may also be required due to accidents or unforeseen, extreme events which are not considered since these random acts are less relevant to design.

D3.1 Maintenance

The main maintenance activity which applies to all materials external to the building is washing once a year, except for glazing which is four times a year. The calculated environmental indicators are based on provision of water from a reticulated system and assumes that all water used evaporates rather than drains to a wastewater system (meaning no account of treatment of wastewater is included). No account is taken of use of any detergents and other consumables, nor is the energy that may be required for accessing all parts of the enclosure. The amount of water used for washing is based on an 1 L/m^2.

Washing is modelled based on recommended frequency in order to avoid accumulation of debris, salts etc. However, in practice, building owners may not wash the building enclosure as frequently as indicated, leading over time to a potential need to repair (module B3) or prematurely replace (module B4) some materials.

Specific information about materials and products, where relevant, is provided below.

Membrane systems

Description	A small area of roof membrane systems require application of patches. Data used to represent these patches is based on product manufacture data (modules A1 – A3) and transport & construction (modules A4 – A5) and presented per m^2 per year when patching is required. The total impact of application of patches is calculated based on the office building lifetime (default = 60 years).

Paint

Description	For the purposes of calculating impacts from painting needed for maintenance of materials, the assumption is that products requiring periodic painting originally had a factory applied coating, rather than the first coating being applied at the construction site. This only applies to materials or products where this is an option e.g. steel sheet profiles. Anodised aluminium does not require painting. Based on the module B2 datasheet, where a product has a factory applied coating, the period before first painting for maintenance is longer than if the material or product is first coated at the construction site. The impacts of painting are calculated by taking the module A1 – A3 and module A4 – A5 environmental indicators for the relevant paint, and multiplying these by the area to be painted (e.g. from BIM model outputs) and number of layers. Clear coat and stain are not currently considered.

D3.2 Replacement

Where a material or product requires replacement during the life of a building, environmental indicators are calculated according to the following:

- Production of the material or product to replace the material or product that has reached its estimated service life. This is based on Product stage impacts (modules A1 – A3).
- Transport and installation in the building, based on the Construction Process (modules A4 – A5).

- Waste management and end of life of the removed material or product, based on the End of Life Stage (module C1 – C4).

Any reuse, recycling or recovery of material generated as a result of replacement, may contribute towards module D benefits and loads beyond the system boundary.

Using estimated service life data in the module B4 datasheet, the number of replacements over the life of the building is calculated using the formula in Section 9.3.3 of EN 15978 (CEN, 2011), which is:

NR(j) = E [ReqSL/ESL(j) – 1]

where:

E [ReqSL/ESL(j)] is rounded to the next higher integer.

ESL(j) is the estimated service life for a product "j" (from the module B4 datasheet).

NR(j) is the number of replacements.

ReqSL is the required service life of a building (the default is 60 years for New Zealand office buildings unless otherwise defined in a client's brief, taken from the module B1 to B7 datasheet).

In some cases, where the remaining service life of the building is short in comparison with the estimated service life of a material or product, the number of replacements may be adjusted to reflect the actual likelihood of replacement.

Specific information about materials and products, where relevant, is provided below.

Membrane systems

Description	When a roof membrane system has reached the end of its estimated service life and requires replacement, the assumption is that the existing membrane system is not removed and the new membrane system is placed over it. In practice, this may happen or the old roofing system may be taken up, depending on its condition. Also, plywood (if present) underneath would be inspected and some may be replaced, which is not considered here. For fibre reinforced bitumen membrane systems, the assumption is that each new layer is torched on (based on environmental indicators calculated for modules A4 – A5). In practice however, one layer may be mechanically fixed on the old layer, and then another layer torched on that.

D4. End-of-life stage (modules C1–C4)

Energy required to deconstruct buildings is accounted for concrete, timber and engineered wood (except plywood) and steel products only using data from the Athena Sustainable Materials Institute (1997). This provides a demolition analysis for buildings with a wood, steel and concrete structure. The wood and steel structural systems additionally include use of concrete, for which the energy for demolition is separated.

Using the data in this report, the following tables summarise the analysis that has been undertaken and the resulting demolition energy that has been calculated.

Table 18. Demolition energy for a wood structure (from Table B1 of Athena, 1997).

Material	Mass (kg)	Energy (MJ)	MJ/kg	Notes
Concrete	1040628	209647	0.2015	Above grade
	158203	11362	0.07182	Below grade
	1198831	58082	0.0484	Stockpiling, loading and transport to offsite Municipal Recycling Facility (MRF)
Wood	107096	192998	1.8021	Total wood
	107096	66461	0.6206	Stockpiling, loading and wood chipping for transport to offsite MRF
GRAND TOTAL:	1305927	546895	0.4188	

Table 19. Demolition energy for a steel structure (from Table B3 of Athena, 1997).

Material	Mass (kg)	Energy (MJ)	MJ/kg	Notes
Concrete	1384732	329065	0.2376	Above grade
	158203	11362	0.0718	Below grade
	1542935	70739	0.0458	Stockpiling, loading and transport to offsite MRF
Steel	150978	54185	0.3589	Total steel
	150978	34478	0.2284	Steel preparation, loading and transportation
GRAND TOTAL:	1693913	509605	0.3008	

Table 20. Demolition energy for a concrete structure (from Table B5 of Athena, 1997).

Material	Mass (kg)	Energy (MJ)	MJ/kg	Notes
Concrete	596122	73032	0.1225	Above grade
	158203	11351	0.0718	Below grade
	2935198	169013	0.0576	Above ground horizontal
	700348	43961	0.0628	Above ground vertical
	79636	7006	0.0880	Miscellaneous
	4469475	165378	0.0370	Concrete stockpiling, loading, transport to offsite MRF
	4469477	477886	0.1069	

Table 21. Summary of demolition energy by structural material.

	Total mass (kg)	Energy (MJ)	MJ/kg
Concrete	14422514	1159998	0.080
Wood	214192	259459	1.211
Steel	301956	88663	0.294

Energy per kg figures in the Summary table above have been used. The energy is assumed to be supplied by combustion of diesel**.**

Specific information about materials and products, where relevant, is provided below. Where no specific information is provided, the approach set out in this section is applied.

D4.1 Aggregates

Description	Reused material assumed to remain on site, and therefore has reached its end of waste state. Other material is excavated. For energy use arising from excavation, see **Aggregates** in module A4 - A5.

D4.2 Concrete and cement-containing materials

Description	For the proportion of concrete (block (and grout), in situ, precast) that is crushed for secondary aggregate, the assumption is that a mobile diesel-powered concrete crushing plant is brought to site. Data for energy required by concrete crushers sourced from Wilburn & Goonan (1998). Concrete crushers may also be electrically powered but more likely that a mobile plant is diesel powered. Data do not take into account transport of the concrete crusher to the site and wear and tear on equipment. Energy from diesel required to recover reinforcement from concrete based on EcoInvent data. The amount of reinforcement that is recovered is determined by the proportion of concrete that is crushed for aggregate. Crushed concrete assumed to reach its end of waste state once sorted and graded for sale. Onward transport is therefore excluded. Carbonation is not included.

D4.3 Insulation

Description	Reused material is assumed to reach its end of waste state on removal from the building. No onward transport is considered.

D4.4 Membrane systems

Description	Since replacement roof membranes during the life of a building (module B4) are assumed to be placed on top of the existing membrane, the accumulated mass of membranes over the life of the building is modelled. Accumulation of patches applied due to maintenance (module B2) are not considered, as the mass added is insignificant in comparison with replacement. Modelling of landfilling based on constituent materials.

D4.5 Metals and metal-containing composites

Description	<u>Aluminium</u> Scrap preparation based on EcoInvent data "RoW: treatment of aluminium scrap, post-consumer, by collecting, sorting, cleaning, pressing" with the following adjustments: The original data shows a loss rate of 20% by mass of aluminium. This has been adjusted to 25% in line with data in the module C datasheet.

	All inputs and outputs are assumed to show a linear relationship with scrap input and were pro-rated accordingly. Use of NZ Grid electricity (medium voltage). Scrap transported (assumed to travel 5000 km to Australia). Some scrap aluminium is remelted in NZ (by MCK) but it is assumed that the process would not take scrap aluminium from building demolition in large volumes, so this is not specifically considered. Aluminium that is not recycled is landfilled. The end of waste state of the aluminium for recycling is reached following processing (cleaning, shredding, pressing etc) and transport to a remelt facility. Steel Deconstruction energy based on analysis of "Steel – Recycle Case" (Table B1, B3, B5) in Athena (1997) and includes site mobilisation and set up, removal of steel elements using a Caterpillar with hydraulic shear (for selective cutting and pulling), cutting of dislodged steel into smaller sections for loading onto a truck. Cut sections loaded using an excavator with a grapple. Recycled steel is then transported overseas (Australia assumed, with a transport distance of 5000 km based on Distance Mode model in the module A4 datasheet) EcoInvent data used to model C1 (deconstruction/demolition) and C2 (transport) impacts. Impacts arising from C3 waste processing and C4 landfill are based on data provided in the EPD for welded beams and columns from Bluescope (2015). Figures for C3 in the EPD are based on a recycling rate of 89%. These are pro-rated for the recycling rate in the module C datasheet. Similarly, figures for C4 in the EPD are based on a landfill rate of 11%. These are pro-rated for the landfill rate in the module C datasheet. Module C4 impacts based on Bluescope (2015) are similar to those stated in European Association for Panels and Profiles (2013). The end of waste state of the steel for recycling is reached following transport and processing (based on Bluescope (2015) data). The end of waste state for reused steel is at the deconstruction site.

D4.6 Plasterboard

Description	No data found for environmental impacts arising from disposal of plasterboard to landfill. Modelling is therefore an estimate that includes transport to a landfill site and impacts associated with main constituents of plasterboard. Composition % based on thresholds in GIB Material Safety Data Sheet, as follows: Gypsum 65% (SDS states <70%). Inert filler 21% (SDS states <25%). Paper 12% (SDS states <15%) Starch 2% (SDS states <3%). For simplicity, starch and paper added together. EcoInvent datasets used cover impacts of waste gypsum, inert waste and graphical paper in a sanitary landfill, using EcoInvent "Rest of the World" datasets (except gypsum, which is based on Swiss data).

D4.7 Renewable energy infrastructure (on-site)

Description	Treated as inert waste due to lack of data.

D4.8 Timber and engineered wood

Description	**Landfilling** <u>Engineered Wood</u> Impacts arising from landfilling are based on the "Typical" scenario in FWPA (2015a). These are based on a Degradable Organic Fraction (DOCf) of 1.4% from bioreactor experiments on solid wood. From FWPA (2015a), this "can be considered as an upper limit for degradation of carbon in solid timber placed in landfill". <u>Timber</u> Impacts arising from landfilling are based on the "Typical" scenario in FWPA (2015b). These are based on a Degradable Organic Fraction (DOCf) of 0.1% from bioreactor experiments on *radiata* pine. From FWPA (2015b), this "can be considered as an upper limit for degradation of carbon in solid timber placed in landfill". From FWPA (2015a, b), for every kg of carbon converted to landfill gas, 71.2% is released as carbon dioxide and 28.8% is released as methane. No data specifically assessing greenhouse gas emissions from NZ landfills as a result of disposed timber products could be found. However, "typical" landfill emissions have been selected over "NGA" figures from the FWPA EPD (2015a, b) because: By experiment, engineered wood products excavated from landfill have been found to produce little or no landfill gas (Wang et al., 2011; Ximenes *et al.*; 2013). The prevalence of treated timber in New Zealand, which has been found to degrade extremely slowly in landfill conditions (Keene & Smythe, 2009). The report also states that "untreated timber will store carbon for a prolonged period while slowly decaying". The "typical" values are for solid timber whereas "NGA" (Australia National Greenhouse Accounts) values are based on wood tree branches ground to a fine powder under anaerobic conditions. It is highly unlikely that timber disposed to landfill will be in a powder form. EcoInvent 3.1 data "CH: treatment of waste wood, untreated, sanitary landfill" provides greenhouse gas emissions per kg disposed that are in reasonable agreement with "typical" figures. The effect of this selection is significant in that landfill gas greenhouse gas emissions over 100 years are 0.111 kg CO_2 eq./kg, instead of 1.36 kg CO_2 eq./kg (for dressed, kiln dried softwood), comprising only 8% of "NGA" values. This compares with: The default New Zealand value of 1.1 kg CO_2 eq./kg waste (MfE, 2010), which includes wood with a DOCf of 43% (Tonkin & Taylor, 2010). Other public sources of data, for example Wood for Good (www.woodforgood.com), report higher emissions of 1.8 kg CO_2 eq/kg based on an organic carbon conversion of 38.5% for UK emissions. Building level results will need to be tested for their sensitivity to use these values, especially for buildings with greater use of timber and/or engineered wood. <u>Hybrid LVL</u> It is assumed that the steel in the hybrid LVL system is separated for recycling at the building end of life. The energy required for separating is

	based on the same data for separation of steel from concrete (from EcoInvent 3.1). All the LVL is assumed to go to landfill. **Reuse/Recycling** Any product that is reused or recycled is assumed to reach the end of waste state after deconstruction and before any onward transport and processing.

D5. Supplementary information beyond the building life cycle (module D)

Module D information for materials is organised as the sum total of environmental benefits and loads beyond the building life cycle that may be accrued through use of the material in a building, divided according to the following categories (based on a developing draft of the revised ISO 21930 standard):

- Reuse (RU).
- Cascade recycling (CR).
- Energy recovery (ER).
- Material recycling (MR).

For the purposes of calculating benefits, the definition of the "end of waste state" needs to be defined. For materials that reach the "end of waste state" on disposal at the construction site (for example, for materials that have a scrap value), the environmental impacts of onward transport and processing are accounted in module D. For materials that require further processing and/or transport before reaching their "end of waste state", the environmental impacts of this further processing and/or transport are accounted for in the module in which the material becomes waste (for example, module A5 if wasted at the construction site, module B4 if replaced during the life of the building or module C during building demolition or deconstruction).

The definition of the "end of waste state" used to calculate environmental indicators is provided for individual materials and products in the sections preceding this one.

Having defined the "end of waste state", the calculation of any environmental benefits or loads beyond the life cycle of the building being considered is interpreted as follows:

- **Reuse (RU)** – The benefit is taken as the environmental impacts arising from the manufacture of the same product (provided in modules A1 – A3). Any assumptions or limitations of data applied in module A1 – A3 are similarly applied here. This may also include the benefit of avoidance of ship transport for imported product.
- **Cascade recycling (CR)** – This refers to "closed loop" recycling in which a product may be recycled to produce a product with the same properties and capable of fulfilling the same function or a different function (with further processing). This primarily concerns metals.

The benefit of recycling is calculated as follows:

1. The mass of material that is collected for recycling less the recycled content of the collected material. For example, for a steel manufactured with a scrap input of 10% for which 70% is recovered at the building end of life (module C1), the benefit of recycling per kg is applied to 0.6 kg (0.7 kg – 0.1 kg).

2. For the proportion of the collected material that has come from primary production, the environmental impact of processing the collected material and substitution of primary production. For aluminium, primary production to aluminium billet is considered. For steel, production of pig iron is considered.

Calculation of the benefit or load is as set out in Appendix D of the ALCAS document *Requirements for the development of AusLCI datasets* (2014).

- **Energy recovery (ER)** – this only applies to one material, being *Timber Soft Wood, Sawn Kiln-Dried.* For material collected which is used for energy recovery, the environmental impact of producing heat is calculated using the EcoInvent 3.1 dataset "heat production, wood chips from post-consumer wood, at furnace 300 kW" (adapted to remove an input of "carbon dioxide (biotic)" being the uptake of carbon dioxide by the growing tree, which has already been accounted for in module A1 – A3). The benefit is calculated by subtracting the production of heat using natural gas. This is based on the EcoInvent 3.1 dataset "heat production, natural gas, at industrial furnace >100 kW" adapted to include use of New Zealand low voltage Grid electricity, and natural gas exploration, extraction, production and distribution by Sacayon Madrigal (2016).
- **Material recycling (MR) –** Materials may be "downcycled" to fulfil a different purpose from the purpose for which they were used originally. For example, crushing of concrete to produce (secondary) aggregate or use of gypsum in cement manufacture derived from recycled plasterboard. In these cases, the benefit of material recycling is calculated as the production of material that fulfils the same purpose as the secondary product arising from the recycling process. In the concrete example, the benefit is calculated as the environmental impacts arising from quarrying of primary aggregate (which would be necessary if the concrete was not recycled).

Similarly, waste material may be cut into smaller pieces and used for filling gaps, for example. Offcuts of timber may be used in this way. In this case, the benefit of using material in this way has been calculated as substitution of new product (the same as reuse).

Specific information about materials and products, where relevant, is provided below. Where no specific information is provided, the approach set out in this section is applied.

D5.1 Aggregates

Description	The benefit beyond the system boundary of reuse is the avoidance of quarrying of primary material. Reused material is assumed to provide the same properties as quarried material and is therefore treated as a 1:1 replacement. Module D benefits are therefore modelled as quarrying of an equivalent mass of material (based on data for modules A1 – A3 for *Sand* and *Granular Fill*.

D5.2 Concrete and cement-containing materials

Description	Reinforced concrete Waste arises from: Overordering of concrete at construction sites, a proportion of which is washed to recover aggregates (comprising half the mass of the washed concrete). Rates provided in the module A5 datasheet. Deconstruction/demolition of the building at its end of life. A proportion of the concrete is crushed for secondary aggregate. Rates provided in the module C datasheet. The waste material does not reach the "end of waste" state until after washing in (1) above or crushing in (2) above. The impacts of these activities are therefore accounted within the building life cycle. Aggregate obtained through either washing of wet concrete or crushing of cured concrete, substitutes quarrying of primary aggregate. A 1:1 replacement is assumed. Benefit of avoided quarried aggregate represented by module A1 – A3 data for *Sand*. Reinforcement that becomes available in module C is recycled. The benefit of this is taken as substitution of production of pig iron. The environmental benefits of this are based on per kg values calculated from Akkon (2012), taking into account the recycled content and end of life recycling used in the EPD, applied to steel scrap available for recycling (see **Metals and metal-containing composites** below). Fibre cement Waste rates and end of life routes as provided in the module A5 and module C datasheets. Reuse provides a module D benefit being the avoidance of manufacture of **Fibre cement board**, based on module A1 – A3 data. Any impacts due to transport and storage of panels for reuse not considered, nor is any saving in long distance transport due to avoidance of need to import from overseas.

D5.3 Metals and metal-containing composites

Description	The "end of waste state" for metals is reached on disposal at the construction site (module A5) and after processing (for example, separation, baling) in module C. Aluminium For the calculation of Cascade Recycling benefits, modelled as the impacts of an aluminium refining process that takes aluminium scrap and makes aluminium ingot, less production of primary ingot on a 1 for 1 basis. EcoInvent 3.1 data used, being the impacts of "Treatment of aluminium scrap, new, at refiner" less the impacts of aluminium production described in modules A1 – A3 (which are based on data from World Aluminium (2013). Recycling of scrap aluminium begins with reception of scrap and ends with production of aluminium billets. The dataset excludes salt slag processing and dross recycling, as well as an output of unspecified metal for recycling output. Primary production includes unloading of process material, pre-treatment of hot metal, recovery and handling of internal process scrap, batching, metal treatment and casting operations, homogenising, sawing and packaging activities, maintenance and repair of plant and equipment, treatment of

	process air, liquids and solids and production of infrastructure (based on estimate). Galvanised steel, Steel with zinc-aluminium alloy and Steel with zinc aluminium alloy and organic coating For the calculation of Cascade Recycling benefits, Akkon (2012) shows a module D benefit for greenhouse gas impacts of -0.8 kg CO_2 eq, which is derived from an end of life recycling rate of 70% and a scrap input of 18% (internal recycling of scrap). Therefore, per kg of steel collected for recycling the benefit is -0.8/(0.7-0.18) = -1.54kg CO_2 eq. This per kg benefit is applied to the collected steel rate. Benefits/loads for other indicators are calculated in the same way. Structural steel Bluescope (2015) shows a module D benefit for greenhouse gases of -1.22 kg CO_2 eq, which is derived from an end of life recycling rate of 89% and a scrap input of 8.5% post-consumer and 6.5% pre-consumer waste. Therefore, per kg of steel collected for recycling, the benefit is -1.22/(0.89-0.15) = -1.65 kg CO_2 eq/kg scrap. This is applied to the amount of steel that becomes available as scrap. The same approach is applied for other indicators.

D5.4 Plasterboard

Description	The "end of waste state" is reached following crushing. For Material Recycling, crushed gypsum from waste plasterboard replaces the need to quarry gypsum and transport it to New Zealand from Australia (based on Winstone Gypsum website) for use in cement production. A 1 for 1 replacement is assumed. The module D benefit of the substituted quarrying of gypsum is represented by the EcoInvent 3.1 dataset "Gypsum quarry operation". The avoided transport from Australia is calculated by applying the Default Distance in the Distance Mode Model in the module A4 datasheet (5000 km). Crushed gypsum from waste plasterboard may also be used as a soil conditioner. This pathway is not currently represented.

D5.5 Timber and engineered wood

Description	The module A1 – A3 greenhouse gas impact of most timber products is negative, reflecting the absorption of carbon dioxide by growing trees that comprise the product. When a timber product is reused or recycled, the reused or recycled material is available for use instead of new product. Therefore, the Module D greenhouse gas figure is positive rather than negative, reflecting the reuse of timber substitutes for new product produced from recently felled trees that have absorbed carbon dioxide. All other indicators are negative.

Appendix E: Energy and water modelling

This section provides information on the source and derivation of calculated indicator values for non-material data. It is divided into the following sections:

- Section E1: Use stage (module B6 operational energy)
- Section E2: Use stage (module B7 operational water)

E1. Use stage (module B6 operational energy)

	Grid electricity (low voltage) delivered to a building
Description	Underlying LCA model developed by Sacayon Madrigal (2016). This was adapted to calculate environmental indicators for the New Zealand grid based on a 3-year average (2012–2014). Reason for taking this approach is set out in Dowdell et al. (2016).
Platform/source(s) of data	EcoInvent 3.1, adapted and MBIE (2013, 2014, 2015).
Data characteristics	See Sacayon Madrigal (2016).
Age	Represents net electricity generation delivered (and sources of supply) in 2012, 2013 and 2014.
Technology coverage	Includes electricity generation from technologies including wind turbines, geothermal, hydroelectric, coal and gas combustion. Includes distribution.
Geographical coverage	New Zealand in terms of net generation and sources (MBIE 2013, 2014, 2015). Underlying model uses EcoInvent 3.1 data, adapted in part where NZ-specific data available. See Sacayon Madrigal (2016).
Assumptions	Calculation of coal and gas quantities based on net calorific value. LCI calculated for each included year, then weighted according to total net generation in each year included in the 3-year average. Technologies supplying very small quantities of electricity to the grid (e.g. oil and biogas) excluded.
Completeness/ exclusions	See Sacayon Madrigal (2016).
Plausibility check	Original Sacayon Madrigal model yielded a greenhouse gas impact per kWh of 0.186 kg CO_2 eq./kWh, based on generation and distribution in 2013. The 3-year average figure is 0.184 kg CO_2 eq./kWh, comprising results for each of the three assessed years as follows: • 2012: 0.212 kg CO_2 eq./kWh. • 2013: 0.181 kg CO_2 eq./kWh. • 2014: 0.159 kg CO_2 eq./kWh. NZ grid electricity data provided by thinkstep in GaBi is based on 2012. All environmental indicators are therefore higher apart from stratospheric ozone depletion. The greenhouse gas impact is slightly higher than the 2012 greenhouse gas impact calculated using the Sacayon Madrigal model (within 5%). Calculated greenhouse gas impact of 0.184 kg CO_2 eq./kWh is 25% higher than the emission factor provided by MfE for corporate greenhouse gas reporting purposes of 0.138 kg CO_2 eq./kWh, based on 2013 data (MfE, 2013). Coelho (2011) calculated a grid greenhouse gas impact of 0.36 kg CO_2 eq./kWh based on the mix for 2008. The higher figure reflects a higher contribution of fossil fuels in that year (over 34% compared to 20–27%).
Consistency (e.g. with EN 15804)	See Sacayon Madrigal (2016).

Gas combustion is represented using the EcoInvent 3.1 dataset entitled "heat production, natural gas, at boiler, fan burner non-modulating < 00 kW" with gas extraction and transmission data and grid electricity data drawn from the work of Sacayon Madrigal (2016).

The environmental impacts arising from manufacture of photovoltaic panels (including mounting) is accounted for in modules A1–A3 (see section D1.9). The environmental impacts associated with in-use generation of electricity are taken as zero in module B6.

E2. Use stage (module B7 operational water)

WaterCare[20] information for Auckland shows a variety of treatment methods are used for Auckland's tap water supply, including ultrafiltration for water taken from the Waikato River. However, most treatment plants appear to be conventional, and this is assumed for the rest of New Zealand. Environmental impacts associated with tap water supply are therefore based on the EcoInvent 3.1 RoW dataset entitled "tap water production, conventional treatment" with inclusion of use of New Zealand Grid electricity.

Environmental indicators for wastewater treatment are based on the EcoInvent 3.1 RoW dataset entitled "treatment of wastewater, average, capacity 1.1E10l/year" with inclusion of use of New Zealand Grid electricity.

For simplicity, wastewater volume generated during building occupation is assumed to be the same as tap water demand.

[20] www.watercare.co.nz/about-watercare/our-services/water-treatment/Pages/default.aspx

Appendix F: Reference building results

This appendix provides tables of results for each of the reference office buildings for the assessed indicators. Total results are provided with and without consideration of module D.

Tables in section F1 provide module B6 operational energy with plug loads, and tables in section F2 provide module B6 operational energy without plug loads.

F1. Reference office building total impacts and impacts by GFA and NLA (with plug loads in module B6)

Auckland

Whole Building Life Cycle Assessment Reference Building Results for Auckland

Climate Change (100 Year) Impact Potential (kg CO_2 eq.)

Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
60 Year										
A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
A4-A5	24,840	35,777	67,207	122,997	99,748	85,948	266,622	163,173	81,887	244,238
B2, B4	230,449	208,448	296,945	392,205	240,036	226,909	231,898	73,266	261,319	861,915
B6	2,594,886	3,262,638	1,571,591	8,667,148	7,981,988	7,374,194	21,532,452	11,845,281	6,232,360	12,164,672
B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
C1-C4	42,173	57,332	35,933	172,228	136,692	145,193	312,731	185,085	97,008	280,681
D	-53,128	-58,939	-51,317	-415,334	-346,525	-160,430	-406,399	-301,427	-221,596	-534,519
Total excl. D	**3,369,330**	**3,937,376**	**2,390,382**	**12,153,875**	**10,795,995**	**8,743,347**	**28,032,249**	**15,621,989**	**8,285,385**	**18,606,609**
Total incl. D	**3,316,202**	**3,878,437**	**2,339,065**	**11,738,542**	**10,449,470**	**8,582,917**	**27,625,850**	**15,320,563**	**8,063,789**	**18,072,090**
Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
A4-A5	0.22	0.31	0.71	0.29	0.32	0.21	0.22	0.29	0.22	0.36
B2, B4	1.90	1.80	2.73	0.87	0.73	0.59	0.17	0.12	0.70	1.08
B6	25.85	29.52	15.44	19.75	23.26	20.56	16.07	17.61	21.82	17.55
B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
C1-C4	0.35	0.49	0.33	0.37	0.40	0.38	0.23	0.28	0.24	0.35
D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.42	-0.30	-0.46	-0.56	-0.67
Total excl. D	**32.25**	**35.34**	**23.06**	**27.28**	**31.30**	**24.13**	**20.82**	**23.46**	**27.05**	**25.71**
Total incl. D	**31.81**	**34.84**	**22.58**	**26.39**	**30.32**	**23.71**	**20.53**	**22.99**	**26.50**	**25.04**
Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
A4-A5	0.26	0.37	1.53	0.45	0.43	0.25	0.38	0.35	0.35	0.45
B2, B4	2.28	2.12	5.84	1.34	0.97	0.69	0.28	0.15	1.09	1.36
B6	31.02	34.76	33.02	30.23	31.04	24.06	26.81	20.84	33.97	21.95
B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
C1-C4	0.42	0.58	0.71	0.57	0.53	0.44	0.38	0.34	0.38	0.44
D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.49	-0.49	-0.55	-0.87	-0.84
Total excl. D	**38.70**	**41.61**	**49.32**	**41.76**	**41.76**	**28.24**	**34.75**	**27.76**	**42.11**	**32.15**
Total incl. D	**38.17**	**41.01**	**48.31**	**40.40**	**40.46**	**27.75**	**34.25**	**27.21**	**41.25**	**31.31**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
		60 Year									
	A1-A3	2.75E-03	4.99E-03	9.37E-03	1.76E-02	1.51E-02	1.23E-02	4.10E-02	2.51E-02	1.08E-02	3.71E-02
	A4-A5	1.02E-02	8.72E-03	1.31E-02	1.75E-02	1.01E-02	7.83E-03	1.07E-02	3.38E-03	1.09E-02	3.96E-02
	B2, B4	4.14E-02	5.28E-02	2.51E-02	1.41E-01	1.27E-01	1.17E-01	3.42E-01	1.92E-01	9.51E-02	1.95E-01
	B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
	B7	6.52E-03	6.69E-03	5.52E-03	3.00E-02	2.15E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
	C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.30E-02**	**7.38E-02**	**5.39E-02**	**2.11E-01**	**1.77E-01**	**1.60E-01**	**4.76E-01**	**2.69E-01**	**1.37E-01**	**3.36E-01**
	Total incl. D	**6.30E-02**	**7.38E-02**	**5.39E-02**	**2.11E-01**	**1.77E-01**	**1.60E-01**	**4.76E-01**	**2.69E-01**	**1.37E-01**	**3.36E-01**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	2.49E-08	4.32E-08	1.03E-07	4.35E-08	4.98E-08	3.01E-08	3.57E-08	4.69E-08	3.08E-08	5.72E-08
	A4-A5	8.43E-08	7.52E-08	1.21E-07	4.72E-08	4.22E-08	2.06E-08	7.77E-09	8.05E-09	3.99E-08	4.99E-08
	B2, B4	3.51E-07	4.33E-07	2.24E-07	2.86E-07	3.42E-07	2.94E-07	2.30E-07	2.76E-07	2.64E-07	2.31E-07
	B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
	B7	5.38E-08	5.77E-08	5.07E-08	6.45E-08	6.34E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
	C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.32E-07**	**6.14E-07**	**5.06E-07**	**4.53E-07**	**5.06E-07**	**4.04E-07**	**3.33E-07**	**4.06E-07**	**3.87E-07**	**4.19E-07**
	Total incl. D	**5.32E-07**	**6.14E-07**	**5.06E-07**	**4.53E-07**	**5.06E-07**	**4.04E-07**	**3.33E-07**	**4.06E-07**	**3.87E-07**	**4.19E-07**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	2.99E-08	5.09E-08	2.20E-07	6.67E-08	6.64E-08	3.52E-08	5.96E-08	5.56E-08	4.79E-08	7.15E-08
	A4-A5	1.01E-07	8.86E-08	2.58E-07	7.23E-08	5.64E-08	2.41E-08	1.30E-08	9.53E-09	6.22E-08	6.24E-08
	B2, B4	4.22E-07	5.10E-07	4.80E-07	4.38E-07	4.56E-07	3.45E-07	3.83E-07	3.26E-07	4.12E-07	2.88E-07
	B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
	B7	6.46E-08	6.80E-08	1.09E-07	9.87E-08	8.46E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
	C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.39E-07**	**7.23E-07**	**1.08E-06**	**6.93E-07**	**6.76E-07**	**4.72E-07**	**5.55E-07**	**4.80E-07**	**6.02E-07**	**5.24E-07**
	Total incl. D	**6.39E-07**	**7.23E-07**	**1.08E-06**	**6.93E-07**	**6.76E-07**	**4.72E-07**	**5.55E-07**	**4.80E-07**	**6.02E-07**	**5.24E-07**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Acidification Impact Potential (kg SO_2 eq.) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
	60 Year										
	A1-A3	2.67E+02	4.47E+02	1.00E+03	9.76E+02	9.81E+02	8.37E+02	1.81E+03	1.20E+03	7.24E+02	1.85E+03
	A4-A5	4.58E-02	6.09E+01	3.83E-02	8.53E-02	8.87E-02	6.70E+00	1.50E-01	0.00E+00	2.95E+01	1.62E-01
	B2, B4	1.24E+04	1.59E+04	7.54E+03	4.23E+04	3.82E+04	3.52E+04	1.03E+05	5.76E+04	2.85E+04	5.84E+04
	B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
	B7	7.55E+02	1.10E+03	9.86E+02	1.61E+03	1.77E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
	C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.36E+04**	**1.75E+04**	**9.55E+03**	**4.47E+04**	**4.08E+04**	**3.81E+04**	**1.09E+05**	**6.14E+04**	**3.06E+04**	**6.37E+04**
	Total incl. D	**1.36E+04**	**1.75E+04**	**9.55E+03**	**4.47E+04**	**4.08E+04**	**3.81E+04**	**1.09E+05**	**6.14E+04**	**3.06E+04**	**6.37E+04**
	Lifecycle Module Stage	Z1, Co, S3a / m^2 GFA / year	Z1, Cx, S3 / m^2 GFA / year	Z1, Co, S3b / m^2 GFA / year	Z1, Co, S4a / m^2 GFA / year	Z1, Co, S4b / m^2 GFA / year	Z1, Cx, S4a / m^2 GFA / year	Z1, Cx, S5 / m^2 GFA / year	Z1, Co, S5a / m^2 GFA / year	Z1, Cx, S4b / m^2 GFA / year	Z1, Co, S5b / m^2 GFA / year
	A1-A3	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
	A4-A5	6.23E-03	9.46E-03	9.06E-03	3.46E-03	5.12E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
	B2, B4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
	B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	C1-C4	8.21E-03	5.47E-03	8.17E-03	7.08E-03	9.56E-03	4.43E-03	5.80E-03	7.11E-03	5.91E-03	8.73E-03
	D	4.99E-04	5.60E-04	1.36E-03	5.01E-04	5.72E-04	4.71E-04	3.54E-04	4.88E-04	4.15E-04	6.12E-04
	Total excl. D	**1.61E-02**	**1.48E-02**	**1.74E-02**	**1.02E-02**	**1.43E-02**	**9.82E-03**	**8.77E-03**	**1.10E-02**	**9.20E-03**	**1.29E-02**
	Total incl. D	**1.66E-02**	**1.54E-02**	**1.88E-02**	**1.07E-02**	**1.49E-02**	**1.03E-02**	**9.12E-03**	**1.15E-02**	**9.61E-03**	**1.36E-02**
	Lifecycle Module Stage	Z1, Co, S3a / m^2 NLA / year	Z1, Cx, S3 / m^2 NLA / year	Z1, Co, S3b / m^2 NLA / year	Z1, Co, S4a / m^2 NLA / year	Z1, Co, S4b / m^2 NLA / year	Z1, Cx, S4a / m^2 NLA / year	Z1, Cx, S5 / m^2 NLA / year	Z1, Co, S5a / m^2 NLA / year	Z1, Cx, S4b / m^2 NLA / year	Z1, Co, S5b / m^2 NLA / year
	A1-A3	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
	A4-A5	7.47E-03	1.11E-02	1.94E-02	5.30E-03	6.84E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
	B2, B4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
	B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	C1-C4	9.85E-03	6.45E-03	1.75E-02	1.08E-02	1.28E-02	5.19E-03	9.68E-03	8.42E-03	9.20E-03	1.09E-02
	D	5.99E-04	6.59E-04	2.90E-03	7.67E-04	7.64E-04	5.51E-04	5.91E-04	5.77E-04	6.46E-04	7.66E-04
	Total excl. D	**1.93E-02**	**1.74E-02**	**3.73E-02**	**1.56E-02**	**1.91E-02**	**1.15E-02**	**1.46E-02**	**1.31E-02**	**1.43E-02**	**1.62E-02**
	Total incl. D	**1.99E-02**	**1.81E-02**	**4.02E-02**	**1.63E-02**	**1.98E-02**	**1.20E-02**	**1.52E-02**	**1.36E-02**	**1.50E-02**	**1.70E-02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Eutrophication Impact Potential (kg PO_4^{3-} eq.) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
	60 Year										
	A1-A3	5.90E+01	6.46E+01	1.35E+02	2.19E+02	1.87E+02	1.85E+02	4.38E+02	2.85E+02	1.57E+02	4.37E+02
	A4-A5	4.71E+02	3.55E+02	5.95E+02	8.15E+02	3.74E+02	5.04E-01	5.55E+02	1.76E+02	4.03E+02	2.05E+03
	B2, B4	5.90E+03	7.54E+03	3.58E+03	2.01E+04	1.81E+04	1.67E+04	4.88E+04	2.74E+04	1.35E+04	2.78E+04
	B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
	B7	1.76E+02	2.37E+02	2.40E+02	9.38E+02	7.12E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
	C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.69E+03**	**9.23E+03**	**5.06E+03**	**2.53E+04**	**2.23E+04**	**2.11E+04**	**5.96E+04**	**3.45E+04**	**1.77E+04**	**3.82E+04**
	Total incl. D	**7.69E+03**	**9.23E+03**	**5.06E+03**	**2.53E+04**	**2.23E+04**	**2.11E+04**	**5.96E+04**	**3.45E+04**	**1.77E+04**	**3.82E+04**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	A4-A5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B2, B4	3.71E-03	2.82E-03	3.53E-03	4.13E-03	5.31E-03	2.38E-03	2.89E-03	3.71E-03	2.91E-03	4.51E-03
	B6	1.82E-04	4.05E-04	7.38E-04	2.44E-04	2.84E-04	2.60E-04	1.87E-04	2.47E-04	1.77E-04	3.18E-04
	B7	5.22E-04	8.19E-04	8.33E-04	2.40E-04	4.86E-04	1.10E-03	1.09E-07	9.45E-06	4.58E-04	1.63E-05
	C1-C4	6.57E-03	8.04E-03	4.17E-03	5.32E-03	6.34E-03	5.48E-03	4.27E-03	5.09E-03	5.00E-03	4.33E-03
	D	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
	Total excl. D	**1.10E-02**	**1.21E-02**	**9.26E-03**	**9.93E-03**	**1.24E-02**	**9.22E-03**	**7.35E-03**	**9.05E-03**	**8.55E-03**	**9.18E-03**
	Total incl. D	**1.12E-02**	**1.23E-02**	**9.40E-03**	**1.01E-02**	**1.26E-02**	**9.46E-03**	**7.52E-03**	**9.29E-03**	**8.73E-03**	**9.40E-03**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	A4-A5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B2, B4	4.45E-03	3.32E-03	7.54E-03	6.32E-03	7.09E-03	2.79E-03	4.82E-03	4.39E-03	4.53E-03	5.65E-03
	B6	2.19E-04	4.76E-04	1.58E-03	3.73E-04	3.79E-04	3.04E-04	3.12E-04	2.92E-04	2.75E-04	3.97E-04
	B7	6.27E-04	9.65E-04	1.78E-03	3.67E-04	6.48E-04	1.29E-03	1.82E-07	1.12E-05	7.12E-04	2.04E-05
	C1-C4	7.89E-03	9.47E-03	8.91E-03	8.14E-03	8.46E-03	6.41E-03	7.13E-03	6.02E-03	7.79E-03	5.41E-03
	D	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
	Total excl. D	**1.32E-02**	**1.42E-02**	**1.98E-02**	**1.52E-02**	**1.66E-02**	**1.08E-02**	**1.23E-02**	**1.07E-02**	**1.33E-02**	**1.15E-02**
	Total incl. D	**1.35E-02**	**1.45E-02**	**2.01E-02**	**1.55E-02**	**1.69E-02**	**1.11E-02**	**1.25E-02**	**1.10E-02**	**1.36E-02**	**1.18E-02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Tropospheric Ozone Formation Impact Potential (kg C_2H_2 eq.) Impact	**Lifecycle Module Stage**	**Z1, Co, S3a**	**Z1, Cx, S3**	**Z1, Co, S3b**	**Z1, Co, S4a**	**Z1, Co, S4b**	**Z1, Cx, S4a**	**Z1, Cx, S5**	**Z1, Co, S5a**	**Z1, Cx, S4b**	**Z1, Co, S5b**
						60 Year					
	A1-A3	2.68E+01	4.88E+01	7.69E+01	1.20E+02	1.02E+02	1.06E+02	2.50E+02	1.53E+02	7.65E+01	2.38E+02
	A4-A5	6.33E+01	9.50E+01	9.07E+01	9.69E+01	1.56E+02	4.21E+02	1.50E-01	0.00E+00	1.65E+02	1.29E+01
	B2, B4	7.62E+02	9.72E+02	4.62E+02	2.59E+03	2.34E+03	2.16E+03	6.30E+03	3.53E+03	1.76E+03	3.59E+03
	B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
	B7	4.91E+01	4.10E+02	5.47E+01	1.70E+02	1.39E+02	8.05E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
	C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**8.85E+02**	**1.51E+03**	**6.54E+02**	**2.83E+03**	**2.64E+03**	**3.50E+03**	**6.92E+03**	**3.88E+03**	**2.07E+03**	**4.06E+03**
	Total incl. D	**8.85E+02**	**1.51E+03**	**6.54E+02**	**2.83E+03**	**2.64E+03**	**3.50E+03**	**6.92E+03**	**3.88E+03**	**2.07E+03**	**4.06E+03**
	Lifecycle Module Stage	**Z1, Co, S3a / m² GFA / year**	**Z1, Cx, S3 / m² GFA / year**	**Z1, Co, S3b / m² GFA / year**	**Z1, Co, S4a / m² GFA / year**	**Z1, Co, S4b / m² GFA / year**	**Z1, Cx, S4a / m² GFA / year**	**Z1, Cx, S5 / m² GFA / year**	**Z1, Co, S5a / m² GFA / year**	**Z1, Cx, S4b / m² GFA / year**	**Z1, Co, S5b / m² GFA / year**
	A1-A3	2.25E-05	5.62E-07	2.70E-05	4.41E-07	5.93E-07	4.50E-07	3.06E-07	7.02E-07	3.21E-06	5.00E-07
	A4-A5	3.85E-07	5.08E-07	3.63E-07	3.33E-07	4.59E-07	3.11E-07	1.10E-07	4.34E-08	4.15E-07	2.08E-07
	B2, B4	5.72E-05	7.01E-05	3.63E-05	4.64E-05	5.53E-05	4.78E-05	3.73E-05	4.44E-05	4.35E-05	3.77E-05
	B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
	B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.70E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
	C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**-1.15E-03**	**-9.75E-04**	**-1.50E-03**	**-5.15E-04**	**-4.42E-04**	**-9.98E-04**	**-6.90E-04**	**-9.16E-04**	**-6.62E-04**	**-1.12E-03**
	Total incl. D	**-1.15E-03**	**-9.75E-04**	**-1.50E-03**	**-5.15E-04**	**-4.42E-04**	**-9.98E-04**	**-6.90E-04**	**-9.16E-04**	**-6.62E-04**	**-1.12E-03**
	Lifecycle Module Stage	**Z1, Co, S3a / m² NLA / year**	**Z1, Cx, S3 / m² NLA / year**	**Z1, Co, S3b / m² NLA / year**	**Z1, Co, S4a / m² NLA / year**	**Z1, Co, S4b / m² NLA / year**	**Z1, Cx, S4a / m² NLA / year**	**Z1, Cx, S5 / m² NLA / year**	**Z1, Co, S5a / m² NLA / year**	**Z1, Cx, S4b / m² NLA / year**	**Z1, Co, S5b / m² NLA / year**
	A1-A3	2.70E-05	6.62E-07	5.78E-05	6.75E-07	7.91E-07	5.26E-07	5.10E-07	8.31E-07	4.99E-06	6.25E-07
	A4-A5	4.62E-07	5.98E-07	7.76E-07	5.10E-07	6.12E-07	3.64E-07	1.83E-07	5.14E-08	6.46E-07	2.61E-07
	B2, B4	6.87E-05	8.25E-05	7.77E-05	7.10E-05	7.38E-05	5.59E-05	6.22E-05	5.26E-05	6.77E-05	4.71E-05
	B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
	B7	3.67E-07	5.34E-07	4.98E-07	6.88E-07	7.60E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
	C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**-1.38E-03**	**-1.15E-03**	**-3.22E-03**	**-7.89E-04**	**-5.90E-04**	**-1.17E-03**	**-1.15E-03**	**-1.08E-03**	**-1.03E-03**	**-1.40E-03**
	Total incl. D	**-1.38E-03**	**-1.15E-03**	**-3.22E-03**	**-7.89E-04**	**-5.90E-04**	**-1.17E-03**	**-1.15E-03**	**-1.08E-03**	**-1.03E-03**	**-1.40E-03**

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Auckland										
Lifecycle Module Stage	**Z1, Co, S3a**	**Z1, Cx, S3**	**Z1, Co, S3b**	**Z1, Co, S4a**	**Z1, Co, S4b**	**Z1, Cx, S4a**	**Z1, Cx, S5**	**Z1, Co, S5a**	**Z1, Cx, S4b**	**Z1, Co, S5b**
	60 Year									
1.275172	2.73E+00	6.47E-02	2.92E+00	1.72E-01	1.79E-01	1.81E-01	3.22E-01	3.91E-01	1.26E+00	2.96E-01
0.164863	4.67E-02	5.89E-02	3.95E-02	8.68E-02	8.96E-02	1.18E-01	1.51E-01	3.02E-04	9.01E-02	1.66E-01
17.27836	6.65E+00	8.49E+00	4.04E+00	2.26E+01	2.05E+01	1.89E+01	5.51E+01	3.08E+01	1.53E+01	3.13E+01
0.624335	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
0.163722	3.71E-02	5.26E-02	2.53E-02	2.10E-01	1.99E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
-282.6095	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.40E+02**	**-1.13E+02**	**-1.64E+02**	**-2.40E+02**	**-1.56E+02**	**-3.81E+02**	**-9.44E+02**	**-5.96E+02**	**-2.65E+02**	**-8.86E+02**
Total incl. D	**-1.40E+02**	**-1.13E+02**	**-1.64E+02**	**-2.40E+02**	**-1.56E+02**	**-3.81E+02**	**-9.44E+02**	**-5.96E+02**	**-2.65E+02**	**-8.86E+02**
Lifecycle Module Stage	**Z1, Co, S3a / m² GFA / year**	**Z1, Cx, S3 / m² GFA / year**	**Z1, Co, S3b / m² GFA / year**	**Z1, Co, S4a / m² GFA / year**	**Z1, Co, S4b / m² GFA / year**	**Z1, Cx, S4a / m² GFA / year**	**Z1, Cx, S5 / m² GFA / year**	**Z1, Co, S5a / m² GFA / year**	**Z1, Cx, S4b / m² GFA / year**	**Z1, Co, S5b / m² GFA / year**
A1-A3	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
A4-A5	4.76E+00	5.95E+00	4.41E+00	5.66E+00	5.64E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.79E+00
B2, B4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1-C4	4.16E+01	6.63E+01	3.95E+01	6.12E+01	7.23E+01	5.87E+01	3.42E+01	4.51E+01	4.08E+01	5.86E+01
D	3.37E+00	4.93E+00	1.05E+01	4.67E+00	5.37E+00	4.17E+00	3.25E+00	4.38E+00	3.38E+00	5.43E+00
Total excl. D	**4.44E+01**	**7.10E+01**	**3.93E+01**	**6.08E+01**	**7.32E+01**	**6.35E+01**	**3.82E+01**	**4.91E+01**	**4.32E+01**	**6.20E+01**
Total incl. D	**4.78E+01**	**7.60E+01**	**4.99E+01**	**6.55E+01**	**7.86E+01**	**6.77E+01**	**4.14E+01**	**5.35E+01**	**4.65E+01**	**6.74E+01**
Lifecycle Module Stage	**Z1, Co, S3a / m² NLA / year**	**Z1, Cx, S3 / m² NLA / year**	**Z1, Co, S3b / m² NLA / year**	**Z1, Co, S4a / m² NLA / year**	**Z1, Co, S4b / m² NLA / year**	**Z1, Cx, S4a / m² NLA / year**	**Z1, Cx, S5 / m² NLA / year**	**Z1, Co, S5a / m² NLA / year**	**Z1, Cx, S4b / m² NLA / year**	**Z1, Co, S5b / m² NLA / year**
A1-A3	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
A4-A5	5.71E+00	7.01E+00	9.44E+00	8.66E+00	7.52E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
B2, B4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C1-C4	5.00E+01	7.81E+01	8.44E+01	9.37E+01	9.65E+01	6.87E+01	5.71E+01	5.33E+01	6.35E+01	7.33E+01
D	4.04E+00	5.80E+00	2.25E+01	7.14E+00	7.17E+00	4.88E+00	5.43E+00	5.18E+00	5.26E+00	6.80E+00
Total excl. D	**5.33E+01**	**8.36E+01**	**8.42E+01**	**9.31E+01**	**9.77E+01**	**7.43E+01**	**6.37E+01**	**5.81E+01**	**6.72E+01**	**7.75E+01**
Total incl. D	**5.73E+01**	**8.94E+01**	**1.07E+02**	**1.00E+02**	**1.05E+02**	**7.92E+01**	**6.91E+01**	**6.33E+01**	**7.24E+01**	**8.43E+01**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
	60 Year										
	A1-A3	3.14E+05	5.00E+05	8.96E+05	1.74E+06	1.45E+06	1.38E+06	3.60E+06	2.25E+06	1.11E+06	3.40E+06
	A4-A5	2.58E+06	2.40E+06	3.33E+06	4.39E+06	2.72E+06	2.69E+06	2.57E+06	8.12E+05	2.99E+06	9.56E+06
	B2, B4	1.84E+07	2.33E+07	1.12E+07	6.19E+07	5.66E+07	5.23E+07	1.53E+08	8.46E+07	4.35E+07	8.65E+07
	B6	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	B7	5.77E+05	6.90E+05	4.80E+05	2.64E+06	1.92E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	C1-C4	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.16E+07**	**2.67E+07**	**1.54E+07**	**6.78E+07**	**6.10E+07**	**5.82E+07**	**1.64E+08**	**9.02E+07**	**4.85E+07**	**1.02E+08**
	Total incl. D	**2.16E+07**	**2.67E+07**	**1.54E+07**	**6.78E+07**	**6.10E+07**	**5.82E+07**	**1.64E+08**	**9.02E+07**	**4.85E+07**	**1.02E+08**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	3.48E+01	4.33E+01	3.57E+01	5.36E+01	6.04E+01	3.70E+01	3.09E+01	4.08E+01	3.48E+01	5.20E+01
	A4-A5	2.81E+00	4.48E+00	9.97E+00	4.29E+00	4.76E+00	3.60E+00	3.15E+00	4.22E+00	3.18E+00	5.24E+00
	B2, B4	2.38E+01	2.31E+01	3.42E+01	1.19E+01	1.05E+01	7.69E+00	2.10E+00	1.81E+00	1.01E+01	1.35E+01
	B6	1.75E+02	2.05E+02	1.07E+02	1.36E+02	1.61E+02	1.41E+02	1.10E+02	1.25E+02	1.42E+02	1.17E+02
	B7	3.43E+00	3.49E+00	1.92E+00	2.69E+00	3.08E+00	3.51E+00	2.46E+00	3.47E+00	2.64E+00	3.29E+00
	C1-C4	4.84E+00	6.06E+00	4.20E+00	5.76E+00	5.74E+00	4.78E+00	4.02E+00	4.90E+00	3.83E+00	5.88E+00
	D	-5.15E+00	-4.52E+00	-6.24E+00	-8.57E+00	-7.66E+00	-3.21E+00	-2.27E+00	-4.01E+00	-3.88E+00	-5.43E+00
	Total excl. D	**2.44E+02**	**2.85E+02**	**1.93E+02**	**2.15E+02**	**2.46E+02**	**1.98E+02**	**1.53E+02**	**1.80E+02**	**1.97E+02**	**1.97E+02**
	Total incl. D	**2.39E+02**	**2.81E+02**	**1.86E+02**	**2.06E+02**	**2.38E+02**	**1.95E+02**	**1.51E+02**	**1.76E+02**	**1.93E+02**	**1.92E+02**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	4.18E+01	5.10E+01	7.64E+01	8.21E+01	8.06E+01	4.33E+01	5.16E+01	4.82E+01	5.42E+01	6.50E+01
	A4-A5	3.38E+00	5.27E+00	2.13E+01	6.56E+00	6.35E+00	4.21E+00	5.25E+00	5.00E+00	4.94E+00	6.55E+00
	B2, B4	2.86E+01	2.72E+01	7.32E+01	1.82E+01	1.40E+01	9.00E+00	3.51E+00	2.14E+00	1.58E+01	1.69E+01
	B6	2.09E+02	2.41E+02	2.28E+02	2.09E+02	2.15E+02	1.65E+02	1.84E+02	1.48E+02	2.21E+02	1.47E+02
	B7	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00
	C1-C4	5.81E+00	7.13E+00	8.99E+00	8.82E+00	7.66E+00	5.60E+00	6.70E+00	5.80E+00	5.96E+00	7.36E+00
	D	-6.18E+00	-5.32E+00	-1.33E+01	-1.31E+01	-1.02E+01	-3.75E+00	-3.79E+00	-4.75E+00	-6.04E+00	-6.79E+00
	Total excl. D	**2.93E+02**	**3.36E+02**	**4.12E+02**	**3.28E+02**	**3.28E+02**	**2.32E+02**	**2.55E+02**	**2.13E+02**	**3.06E+02**	**2.46E+02**
	Total incl. D	**2.87E+02**	**3.30E+02**	**3.99E+02**	**3.15E+02**	**3.18E+02**	**2.28E+02**	**2.52E+02**	**2.08E+02**	**3.00E+02**	**2.40E+02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland											
Total Primary Energy (MJ) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
		60 Year									
	A1-A3	3.88E+05	5.68E+05	9.75E+05	1.95E+06	1.69E+06	1.66E+06	3.78E+06	2.38E+06	1.22E+06	3.61E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	4.91E+06	3.03E+06	2.94E+06	2.89E+06	9.13E+05	3.35E+06	1.07E+07
	B2, B4	5.65E+07	7.21E+07	3.43E+07	1.92E+08	1.74E+08	1.60E+08	4.68E+08	2.62E+08	1.31E+08	2.66E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.98E+05	7.20E+05	4.66E+05	2.74E+06	2.00E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.02E+07**	**7.59E+07**	**3.90E+07**	**1.99E+08**	**1.79E+08**	**1.67E+08**	**4.81E+08**	**2.68E+08**	**1.37E+08**	**2.84E+08**
	Total incl. D	**6.02E+07**	**7.59E+07**	**3.90E+07**	**1.99E+08**	**1.79E+08**	**1.67E+08**	**4.81E+08**	**2.68E+08**	**1.37E+08**	**2.84E+08**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	9.55E-02	1.53E-01	8.05E-02	1.17E-01	1.29E-01	1.28E-01	7.78E-02	9.45E-02	8.75E-02	1.20E-01
	A4-A5	-1.24E+00	-1.76E+00	-6.73E-01	-1.28E+00	-1.92E+00	-8.59E-01	-3.24E-01	-4.63E-01	-8.61E-01	-7.50E-01
	B2, B4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	C1-C4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**-1.15E+00**	**-1.61E+00**	**-5.93E-01**	**-1.17E+00**	**-1.79E+00**	**-7.31E-01**	**-2.46E-01**	**-3.68E-01**	**-7.73E-01**	**-6.31E-01**
	Total incl. D	**-1.15E+00**	**-1.61E+00**	**-5.93E-01**	**-1.17E+00**	**-1.79E+00**	**-7.31E-01**	**-2.46E-01**	**-3.68E-01**	**-7.73E-01**	**-6.31E-01**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	1.15E-01	1.80E-01	1.72E-01	1.79E-01	1.72E-01	1.49E-01	1.30E-01	1.12E-01	1.36E-01	1.50E-01
	A4-A5	-1.49E+00	-2.07E+00	-1.44E+00	-1.97E+00	-2.56E+00	-1.01E+00	-5.40E-01	-5.47E-01	-1.34E+00	-9.39E-01
	B2, B4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	B7	Z1, Co, S5b / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year
	C1-C4	7.35E+00	5.48E+00	6.30E+00	5.71E+00	2.18E+00	8.19E+00	8.56E+00	7.62E+00	4.11E+00	3.18E+00
	D	4.53E-01	3.49E-01	3.75E-01	3.50E-01	2.51E-01	4.25E-01	4.49E-01	1.53E+00	2.60E-01	3.65E-01
	Total excl. D	**5.97E+00**	**3.59E+00**	**5.03E+00**	**3.92E+00**	**-2.07E-01**	**7.33E+00**	**8.15E+00**	**7.19E+00**	**2.91E+00**	**2.39E+00**
	Total incl. D	**6.42E+00**	**3.94E+00**	**5.40E+00**	**4.27E+00**	**4.42E-02**	**7.76E+00**	**8.60E+00**	**8.71E+00**	**3.17E+00**	**2.76E+00**

Wellington

Whole Building Life Cycle Assessment Reference Building Results for Wellington

Climate Change (100 Year) Impact Potential (kg CO2 eq.)

Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
					60 Year					
A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
A4-A5	26,251	35,989	77,606	137,109	113,002	81,945	309,219	192,110	89,401	288,046
B2, B4	230,449	208,448	296,945	408,794	257,629	227,009	231,898	80,012	279,324	861,915
B6	3,134,302	3,424,180	1,680,150	9,229,629	8,249,476	7,861,436	22,085,057	11,477,024	8,675,397	13,949,358
B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
C1-C4	42,229	57,336	35,933	172,766	142,100	145,193	312,731	185,085	97,008	280,688
D	- 53,128	- 58,939	- 51,317	- 415,334	- 346,525	- 160,430	- 406,399	- 301,427	- 221,596	- 534,519
Total excl. D	**3,910,215**	**4,099,134**	**2,509,341**	**12,747,596**	**11,099,738**	**9,226,686**	**28,627,451**	**15,289,416**	**10,753,940**	**20,435,111**
Total incl. D	**3,857,087**	**4,040,195**	**2,458,023**	**12,332,262**	**10,753,214**	**9,066,255**	**28,221,052**	**14,987,989**	**10,532,344**	**19,900,592**
Lifecycle Module Stage	**Z2, Co, S3a / m² GFA / year**	**Z2, Cx, S3 / m² GFA / year**	**Z2, Co, S3b / m² GFA / year**	**Z2, Co, S4a / m² GFA / year**	**Z2, Co, S4b / m² GFA / year**	**Z2, Cx, S4a / m² GFA / year**	**Z2, Cx, S5 / m² GFA / year**	**Z2, Co, S5a / m² GFA / year**	**Z2, Cx, S4b / m² GFA / year**	**Z2, Co, S5b / m² GFA / year**
A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
A4-A5	0.22	0.31	0.71	0.29	0.32	0.21	0.22	0.29	0.22	0.36
B2, B4	1.90	1.80	2.73	0.87	0.73	0.59	0.17	0.12	0.70	1.08
B6	25.85	29.52	15.44	19.75	23.26	20.56	16.07	17.61	21.82	17.55
B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
C1-C4	0.35	0.49	0.33	0.37	0.40	0.38	0.23	0.28	0.24	0.35
D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.42	-0.30	-0.46	-0.56	-0.67
Total excl. D	**32.25**	**35.34**	**23.06**	**27.28**	**31.30**	**24.13**	**20.82**	**23.46**	**27.05**	**25.71**
Total incl. D	**31.81**	**34.84**	**22.58**	**26.39**	**30.32**	**23.71**	**20.53**	**22.99**	**26.50**	**25.04**
Lifecycle Module Stage	**Z2, Co, S3a / m² NLA / year**	**Z2, Cx, S3 / m² NLA / year**	**Z2, Co, S3b / m² NLA / year**	**Z2, Co, S4a / m² NLA / year**	**Z2, Co, S4b / m² NLA / year**	**Z2, Cx, S4a / m² NLA / year**	**Z2, Cx, S5 / m² NLA / year**	**Z2, Co, S5a / m² NLA / year**	**Z2, Cx, S4b / m² NLA / year**	**Z2, Co, S5b / m² NLA / year**
A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
A4-A5	0.26	0.37	1.53	0.45	0.43	0.25	0.38	0.35	0.35	0.45
B2, B4	2.28	2.12	5.84	1.34	0.97	0.69	0.28	0.15	1.09	1.36
B6	31.02	34.76	33.02	30.23	31.04	24.06	26.81	20.84	33.97	21.95
B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
C1-C4	0.42	0.58	0.71	0.57	0.53	0.44	0.38	0.34	0.38	0.44
D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.49	-0.49	-0.55	-0.87	-0.84
Total excl. D	**38.70**	**41.61**	**49.32**	**41.76**	**41.76**	**28.24**	**34.75**	**27.76**	**42.11**	**32.15**
Total incl. D	**38.17**	**41.01**	**48.31**	**40.40**	**40.46**	**27.75**	**34.25**	**27.21**	**41.25**	**31.31**

Whole Building Life Cycle Assessment Reference Building Results for Wellington

Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact

Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
60 Year										
A1-A3	3.02E-03	5.01E-03	1.12E-02	2.03E-02	1.76E-02	1.15E-02	4.91E-02	3.06E-02	1.22E-02	4.54E-02
A4-A5	1.02E-02	8.72E-03	1.31E-02	2.21E-02	1.50E-02	7.86E-03	1.07E-02	5.25E-03	1.59E-02	3.96E-02
B2, B4	4.26E-02	5.02E-02	2.44E-02	1.34E-01	1.21E-01	1.13E-01	3.16E-01	1.80E-01	1.05E-01	1.83E-01
B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
B7	6.52E-03	6.69E-03	5.52E-03	3.01E-02	2.25E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**6.46E-02**	**7.12E-02**	**5.51E-02**	**2.12E-01**	**1.80E-01**	**1.54E-01**	**4.57E-01**	**2.65E-01**	**1.54E-01**	**3.33E-01**
Total incl. D	**6.46E-02**	**7.12E-02**	**5.51E-02**	**2.12E-01**	**1.80E-01**	**1.54E-01**	**4.57E-01**	**2.65E-01**	**1.54E-01**	**3.33E-01**
Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
A1-A3	2.49E-08	4.32E-08	1.03E-07	4.35E-08	4.98E-08	3.01E-08	3.57E-08	4.69E-08	3.08E-08	5.72E-08
A4-A5	8.43E-08	7.52E-08	1.21E-07	4.72E-08	4.22E-08	2.06E-08	7.77E-09	8.05E-09	3.99E-08	4.99E-08
B2, B4	3.51E-07	4.33E-07	2.24E-07	2.86E-07	3.42E-07	2.94E-07	2.30E-07	2.76E-07	2.64E-07	2.31E-07
B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
B7	5.38E-08	5.77E-08	5.07E-08	6.45E-08	6.34E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**5.32E-07**	**6.14E-07**	**5.06E-07**	**4.53E-07**	**5.06E-07**	**4.04E-07**	**3.33E-07**	**4.06E-07**	**3.87E-07**	**4.19E-07**
Total incl. D	**5.32E-07**	**6.14E-07**	**5.06E-07**	**4.53E-07**	**5.06E-07**	**4.04E-07**	**3.33E-07**	**4.06E-07**	**3.87E-07**	**4.19E-07**
Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
A1-A3	2.99E-08	5.09E-08	2.20E-07	6.67E-08	6.64E-08	3.52E-08	5.96E-08	5.56E-08	4.79E-08	7.15E-08
A4-A5	1.01E-07	8.86E-08	2.58E-07	7.23E-08	5.64E-08	2.41E-08	1.30E-08	9.53E-09	6.22E-08	6.24E-08
B2, B4	4.22E-07	5.10E-07	4.80E-07	4.38E-07	4.56E-07	3.45E-07	3.83E-07	3.26E-07	4.12E-07	2.88E-07
B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
B7	6.46E-08	6.80E-08	1.09E-07	9.87E-08	8.46E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**6.39E-07**	**7.23E-07**	**1.08E-06**	**6.93E-07**	**6.76E-07**	**4.72E-07**	**5.55E-07**	**4.80E-07**	**6.02E-07**	**5.24E-07**
Total incl. D	**6.39E-07**	**7.23E-07**	**1.08E-06**	**6.93E-07**	**6.76E-07**	**4.72E-07**	**5.55E-07**	**4.80E-07**	**6.02E-07**	**5.24E-07**

Acidification Impact Potential (kg SO2 eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Wellington										
Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
60 Year										
A1-A3	2.71E+02	4.48E+02	1.05E+03	1.02E+03	1.03E+03	8.20E+02	1.98E+03	1.31E+03	7.52E+02	2.02E+03
A4-A5	4.58E-02	6.09E+01	3.83E-02	8.29E+01	8.79E+01	7.20E+00	1.50E-01	3.37E+01	1.19E+02	1.62E-01
B2, B4	1.27E+04	1.51E+04	7.31E+03	4.00E+04	3.63E+04	3.37E+04	9.46E+04	5.39E+04	3.13E+04	5.48E+04
B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
B7	7.55E+02	1.10E+03	9.86E+02	1.62E+03	1.82E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.40E+04**	**1.66E+04**	**9.37E+03**	**4.26E+04**	**3.91E+04**	**3.66E+04**	**1.01E+05**	**5.78E+04**	**3.35E+04**	**6.02E+04**
Total incl. D	**1.40E+04**	**1.66E+04**	**9.37E+03**	**4.26E+04**	**3.91E+04**	**3.66E+04**	**1.01E+05**	**5.78E+04**	**3.35E+04**	**6.02E+04**
Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
A1-A3	2.23E-03	3.86E-03	9.60E-03	2.19E-03	2.90E-03	2.14E-03	1.44E-03	2.01E-03	1.89E-03	2.55E-03
A4-A5	3.77E-07	5.25E-04	3.52E-07	1.77E-04	2.48E-04	1.88E-05	1.09E-07	5.17E-05	3.00E-04	2.04E-07
B2, B4	1.05E-01	1.30E-01	6.72E-02	8.57E-02	1.02E-01	8.82E-02	6.88E-02	8.27E-02	7.88E-02	6.89E-02
B6	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
B7	6.23E-03	9.46E-03	9.06E-03	3.46E-03	5.12E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
C1-C4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.15E-01**	**1.44E-01**	**8.61E-02**	**9.11E-02**	**1.10E-01**	**9.57E-02**	**7.32E-02**	**8.87E-02**	**8.43E-02**	**7.57E-02**
Total incl. D	**1.15E-01**	**1.44E-01**	**8.61E-02**	**9.11E-02**	**1.10E-01**	**9.57E-02**	**7.32E-02**	**8.87E-02**	**8.43E-02**	**7.57E-02**
Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
A1-A3	2.68E-03	4.55E-03	2.05E-02	3.34E-03	3.87E-03	2.51E-03	2.40E-03	2.38E-03	2.95E-03	3.19E-03
A4-A5	4.53E-07	6.18E-04	7.53E-07	2.72E-04	3.31E-04	2.20E-05	1.82E-07	6.12E-05	4.68E-04	2.55E-07
B2, B4	1.26E-01	1.53E-01	1.44E-01	1.31E-01	1.37E-01	1.03E-01	1.15E-01	9.79E-02	1.23E-01	8.62E-02
B6	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
B7	7.47E-03	1.11E-02	1.94E-02	5.30E-03	6.84E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
C1-C4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.38E-01**	**1.69E-01**	**1.84E-01**	**1.40E-01**	**1.47E-01**	**1.12E-01**	**1.22E-01**	**1.05E-01**	**1.31E-01**	**9.47E-02**
Total incl. D	**1.38E-01**	**1.69E-01**	**1.84E-01**	**1.40E-01**	**1.47E-01**	**1.12E-01**	**1.22E-01**	**1.05E-01**	**1.31E-01**	**9.47E-02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington											
Eutrophication Impact Potential (kg PO_4^{3-} eq.) Impact	**Lifecycle Module Stage**	**Z2, Co, S3a**	**Z2, Cx, S3**	**Z2, Co, S3b**	**Z2, Co, S4a**	**Z2, Co, S4b**	**Z2, Cx, S4a**	**Z2, Cx, S5**	**Z2, Co, S5a**	**Z2, Cx, S4b**	**Z2, Co, S5b**
	60 Year										
	A1-A3	6.05E+01	6.49E+01	1.48E+02	2.34E+02	2.03E+02	1.80E+02	4.87E+02	3.18E+02	1.65E+02	4.87E+02
	A4-A5	4.71E+02	3.55E+02	5.95E+02	8.44E+02	4.05E+02	6.77E-01	5.55E+02	1.87E+02	4.34E+02	2.05E+03
	B2, B4	6.04E+03	7.14E+03	3.47E+03	1.90E+04	1.72E+04	1.60E+04	4.48E+04	2.56E+04	1.48E+04	2.59E+04
	B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
	B7	1.84E+02	2.38E+02	2.40E+02	9.39E+02	7.23E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
	C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.84E+03**	**8.83E+03**	**4.96E+03**	**2.43E+04**	**2.14E+04**	**2.03E+04**	**5.57E+04**	**3.28E+04**	**1.90E+04**	**3.64E+04**
	Total incl. D	**7.84E+03**	**8.83E+03**	**4.96E+03**	**2.43E+04**	**2.14E+04**	**2.03E+04**	**5.57E+04**	**3.28E+04**	**1.90E+04**	**3.64E+04**
	Lifecycle Module Stage	**Z2, Co, S3a / m² GFA / year**	**Z2, Cx, S3 / m² GFA / year**	**Z2, Co, S3b / m² GFA / year**	**Z2, Co, S4a / m² GFA / year**	**Z2, Co, S4b / m² GFA / year**	**Z2, Cx, S4a / m² GFA / year**	**Z2, Cx, S5 / m² GFA / year**	**Z2, Co, S5a / m² GFA / year**	**Z2, Cx, S4b / m² GFA / year**	**Z2, Co, S5b / m² GFA / year**
	A1-A3	4.99E-04	5.60E-04	1.36E-03	5.01E-04	5.72E-04	4.71E-04	3.54E-04	4.88E-04	4.15E-04	6.12E-04
	A4-A5	3.88E-03	3.06E-03	5.47E-03	1.81E-03	1.14E-03	1.77E-06	4.04E-04	2.87E-04	1.09E-03	2.58E-03
	B2, B4	4.98E-02	6.16E-02	3.19E-02	4.06E-02	4.85E-02	4.18E-02	3.26E-02	3.93E-02	3.73E-02	3.26E-02
	B6	9.46E-03	9.65E-03	5.31E-03	7.42E-03	8.51E-03	9.71E-03	6.81E-03	9.60E-03	7.30E-03	9.08E-03
	B7	1.52E-03	2.05E-03	2.20E-03	2.01E-03	2.04E-03	1.60E-03	5.82E-04	9.60E-04	2.12E-03	1.36E-03
	C1-C4	-5.15E-04	-7.41E-04	-5.85E-04	-3.67E-04	-4.80E-04	-4.08E-04	-2.57E-04	-3.41E-04	-4.49E-04	-4.67E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.46E-02**	**7.61E-02**	**4.56E-02**	**5.20E-02**	**6.03E-02**	**5.32E-02**	**4.05E-02**	**5.03E-02**	**4.77E-02**	**4.58E-02**
	Total incl. D	**6.46E-02**	**7.61E-02**	**4.56E-02**	**5.20E-02**	**6.03E-02**	**5.32E-02**	**4.05E-02**	**5.03E-02**	**4.77E-02**	**4.58E-02**
	Lifecycle Module Stage	**Z2, Co, S3a / m² NLA / year**	**Z2, Cx, S3 / m² NLA / year**	**Z2, Co, S3b / m² NLA / year**	**Z2, Co, S4a / m² NLA / year**	**Z2, Co, S4b / m² NLA / year**	**Z2, Cx, S4a / m² NLA / year**	**Z2, Cx, S5 / m² NLA / year**	**Z2, Co, S5a / m² NLA / year**	**Z2, Cx, S4b / m² NLA / year**	**Z2, Co, S5b / m² NLA / year**
	A1-A3	5.99E-04	6.59E-04	2.90E-03	7.67E-04	7.64E-04	5.51E-04	5.91E-04	5.77E-04	6.46E-04	7.66E-04
	A4-A5	4.66E-03	3.60E-03	1.17E-02	2.76E-03	1.52E-03	2.07E-06	6.74E-04	3.40E-04	1.70E-03	3.22E-03
	B2, B4	5.97E-02	7.25E-02	6.82E-02	6.22E-02	6.48E-02	4.89E-02	5.44E-02	4.65E-02	5.80E-02	4.08E-02
	B6	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
	B7	1.82E-03	2.41E-03	4.71E-03	3.08E-03	2.72E-03	1.87E-03	9.70E-04	1.14E-03	3.30E-03	1.70E-03
	C1-C4	-6.18E-04	-8.72E-04	-1.25E-03	-5.62E-04	-6.41E-04	-4.78E-04	-4.30E-04	-4.03E-04	-6.99E-04	-5.84E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.76E-02**	**8.96E-02**	**9.76E-02**	**7.96E-02**	**8.05E-02**	**6.22E-02**	**6.76E-02**	**5.95E-02**	**7.43E-02**	**5.73E-02**
	Total incl. D	**7.76E-02**	**8.96E-02**	**9.76E-02**	**7.96E-02**	**8.05E-02**	**6.22E-02**	**6.76E-02**	**5.95E-02**	**7.43E-02**	**5.73E-02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington											
Tropospheric Ozone Formation Impact Potential (kg C2H2 eq.) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
		60 Year									
	A1-A3	2.21E+01	4.69E+01	8.03E+01	1.14E+02	1.01E+02	9.92E+01	2.57E+02	1.61E+02	7.03E+01	2.52E+02
	A4-A5	6.33E+01	9.50E+01	9.07E+01	1.12E+02	1.72E+02	4.21E+02	1.50E-01	6.16E+00	1.82E+02	1.29E+01
	B2, B4	7.97E+02	9.33E+02	4.54E+02	2.48E+03	2.25E+03	2.09E+03	5.88E+03	3.32E+03	1.99E+03	3.44E+03
	B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
	B7	4.91E+01	4.10E+02	5.47E+01	1.71E+02	1.46E+02	8.05E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
	C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**9.15E+02**	**1.47E+03**	**6.49E+02**	**2.73E+03**	**2.56E+03**	**3.43E+03**	**6.50E+03**	**3.68E+03**	**2.31E+03**	**3.93E+03**
	Total incl. D	**9.15E+02**	**1.47E+03**	**6.49E+02**	**2.73E+03**	**2.56E+03**	**3.43E+03**	**6.50E+03**	**3.68E+03**	**2.31E+03**	**3.93E+03**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	1.82E-04	4.05E-04	7.38E-04	2.44E-04	2.84E-04	2.60E-04	1.87E-04	2.47E-04	1.77E-04	3.18E-04
	A4-A5	5.22E-04	8.19E-04	8.33E-04	2.40E-04	4.86E-04	1.10E-03	1.09E-07	9.45E-06	4.58E-04	1.63E-05
	B2, B4	6.57E-03	8.04E-03	4.17E-03	5.32E-03	6.34E-03	5.48E-03	4.27E-03	5.09E-03	5.00E-03	4.33E-03
	B6	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
	B7	4.05E-04	3.54E-03	5.03E-04	3.65E-04	4.10E-04	2.10E-03	2.46E-04	3.11E-04	2.69E-04	3.99E-04
	C1-C4	-3.74E-04	-3.77E-04	-4.15E-04	-5.04E-04	-5.01E-04	-2.24E-04	-1.51E-04	-2.49E-04	-2.79E-04	-3.43E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.54E-03**	**1.27E-02**	**5.96E-03**	**5.85E-03**	**7.23E-03**	**8.96E-03**	**4.73E-03**	**5.64E-03**	**5.81E-03**	**4.95E-03**
	Total incl. D	**7.54E-03**	**1.27E-02**	**5.96E-03**	**5.85E-03**	**7.23E-03**	**8.96E-03**	**4.73E-03**	**5.64E-03**	**5.81E-03**	**4.95E-03**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	2.19E-04	4.76E-04	1.58E-03	3.73E-04	3.79E-04	3.04E-04	3.12E-04	2.92E-04	2.75E-04	3.97E-04
	A4-A5	6.27E-04	9.65E-04	1.78E-03	3.67E-04	6.48E-04	1.29E-03	1.82E-07	1.12E-05	7.12E-04	2.04E-05
	B2, B4	7.89E-03	9.47E-03	8.91E-03	8.14E-03	8.46E-03	6.41E-03	7.13E-03	6.02E-03	7.79E-03	5.41E-03
	B6	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
	B7	4.86E-04	4.16E-03	1.08E-03	5.59E-04	5.48E-04	2.46E-03	4.10E-04	3.68E-04	4.19E-04	4.99E-04
	C1-C4	-4.49E-04	-4.44E-04	-8.88E-04	-7.72E-04	-6.68E-04	-2.62E-04	-2.52E-04	-2.95E-04	-4.34E-04	-4.29E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**9.05E-03**	**1.49E-02**	**1.27E-02**	**8.95E-03**	**9.65E-03**	**1.05E-02**	**7.89E-03**	**6.68E-03**	**9.05E-03**	**6.18E-03**
	Total incl. D	**9.05E-03**	**1.49E-02**	**1.27E-02**	**8.95E-03**	**9.65E-03**	**1.05E-02**	**7.89E-03**	**6.68E-03**	**9.05E-03**	**6.18E-03**

Whole Building Life Cycle Assessment Reference Building Results for Wellington

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
					60 Year					
A1-A3	2.73E+00	6.52E-02	2.94E+00	2.06E-01	2.10E-01	1.72E-01	4.20E-01	4.58E-01	1.28E+00	3.97E-01
A4-A5	4.67E-02	5.89E-02	3.95E-02	1.56E-01	1.63E-01	1.19E-01	1.51E-01	2.83E-02	1.65E-01	1.66E-01
B2, B4	6.94E+00	8.13E+00	3.95E+00	2.17E+01	1.96E+01	1.83E+01	5.12E+01	2.89E+01	1.73E+01	2.99E+01
B6	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
B7	3.71E-02	5.26E-02	2.53E-02	2.10E-01	2.02E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
C1-C4	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.40E+02**	**-1.13E+02**	**-1.64E+02**	**-2.41E+02**	**-1.57E+02**	**-3.82E+02**	**-9.48E+02**	**-5.97E+02**	**-2.63E+02**	**-8.87E+02**
Total incl. D	**-1.40E+02**	**-1.13E+02**	**-1.64E+02**	**-2.41E+02**	**-1.57E+02**	**-3.82E+02**	**-9.48E+02**	**-5.97E+02**	**-2.63E+02**	**-8.87E+02**
Lifecycle Module Stage	**Z2, Co, S3a / m² GFA / year**	**Z2, Cx, S3 / m² GFA / year**	**Z2, Co, S3b / m² GFA / year**	**Z2, Co, S4a / m² GFA / year**	**Z2, Co, S4b / m² GFA / year**	**Z2, Cx, S4a / m² GFA / year**	**Z2, Cx, S5 / m² GFA / year**	**Z2, Co, S5a / m² GFA / year**	**Z2, Cx, S4b / m² GFA / year**	**Z2, Co, S5b / m² GFA / year**
A1-A3	2.25E-05	5.62E-07	2.70E-05	4.41E-07	5.93E-07	4.50E-07	3.06E-07	7.02E-07	3.21E-06	5.00E-07
A4-A5	3.85E-07	5.08E-07	3.63E-07	3.33E-07	4.59E-07	3.11E-07	1.10E-07	4.34E-08	4.15E-07	2.08E-07
B2, B4	5.72E-05	7.01E-05	3.63E-05	4.64E-05	5.53E-05	4.78E-05	3.73E-05	4.44E-05	4.35E-05	3.77E-05
B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.70E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.15E-03**	**-9.75E-04**	**-1.50E-03**	**-5.15E-04**	**-4.42E-04**	**-9.98E-04**	**-6.90E-04**	**-9.16E-04**	**-6.62E-04**	**-1.12E-03**
Total incl. D	**-1.15E-03**	**-9.75E-04**	**-1.50E-03**	**-5.15E-04**	**-4.42E-04**	**-9.98E-04**	**-6.90E-04**	**-9.16E-04**	**-6.62E-04**	**-1.12E-03**
Lifecycle Module Stage	**Z2, Co, S3a / m² NLA / year**	**Z2, Cx, S3 / m² NLA / year**	**Z2, Co, S3b / m² NLA / year**	**Z2, Co, S4a / m² NLA / year**	**Z2, Co, S4b / m² NLA / year**	**Z2, Cx, S4a / m² NLA / year**	**Z2, Cx, S5 / m² NLA / year**	**Z2, Co, S5a / m² NLA / year**	**Z2, Cx, S4b / m² NLA / year**	**Z2, Co, S5b / m² NLA / year**
A1-A3	2.70E-05	6.62E-07	5.78E-05	6.75E-07	7.91E-07	5.26E-07	5.10E-07	8.31E-07	4.99E-06	6.25E-07
A4-A5	4.62E-07	5.98E-07	7.76E-07	5.10E-07	6.12E-07	3.64E-07	1.83E-07	5.14E-08	6.46E-07	2.61E-07
B2, B4	6.87E-05	8.25E-05	7.77E-05	7.10E-05	7.38E-05	5.59E-05	6.22E-05	5.26E-05	6.77E-05	4.71E-05
B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
B7	3.67E-07	5.34E-07	4.98E-07	6.88E-07	7.60E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.38E-03**	**-1.15E-03**	**-3.22E-03**	**-7.89E-04**	**-5.90E-04**	**-1.17E-03**	**-1.15E-03**	**-1.08E-03**	**-1.03E-03**	**-1.40E-03**
Total incl. D	**-1.38E-03**	**-1.15E-03**	**-3.22E-03**	**-7.89E-04**	**-5.90E-04**	**-1.17E-03**	**-1.15E-03**	**-1.08E-03**	**-1.03E-03**	**-1.40E-03**

Whole Building Life Cycle Assessment Reference Building Results for Wellington											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A1-A3	3.33E+05	5.03E+05	1.05E+06	1.96E+06	1.65E+06	1.31E+06	4.26E+06	2.70E+06	1.23E+06	4.08E+06
	A4-A5	2.58E+06	2.40E+06	3.33E+06	5.01E+06	3.38E+06	2.69E+06	2.57E+06	1.07E+06	3.66E+06	9.56E+06
	B2, B4	2.10E+07	2.36E+07	1.15E+07	6.33E+07	5.68E+07	5.37E+07	1.51E+08	8.09E+07	5.61E+07	9.25E+07
	B6	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	B7	5.77E+05	6.90E+05	4.80E+05	2.64E+06	2.00E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	C1-C4	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.43E+07**	**2.70E+07**	**1.59E+07**	**7.01E+07**	**6.22E+07**	**5.95E+07**	**1.63E+08**	**8.73E+07**	**6.19E+07**	**1.09E+08**
	Total incl. D	**2.43E+07**	**2.70E+07**	**1.59E+07**	**7.01E+07**	**6.22E+07**	**5.95E+07**	**1.63E+08**	**8.73E+07**	**6.19E+07**	**1.09E+08**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	2.74E+00	4.34E+00	9.66E+00	4.19E+00	4.66E+00	3.44E+00	3.10E+00	4.15E+00	3.09E+00	5.14E+00
	A4-A5	2.13E+01	2.07E+01	3.06E+01	1.07E+01	9.54E+00	7.04E+00	1.87E+00	1.63E+00	9.21E+00	1.20E+01
	B2, B4	1.73E+02	2.03E+02	1.06E+02	1.35E+02	1.60E+02	1.40E+02	1.10E+02	1.24E+02	1.41E+02	1.16E+02
	B6	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
	B7	4.76E+00	5.95E+00	4.41E+00	5.66E+00	5.64E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.79E+00
	C1-C4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.00E+02**	**2.33E+02**	**1.46E+02**	**1.50E+02**	**1.75E+02**	**1.56E+02**	**1.19E+02**	**1.34E+02**	**1.56E+02**	**1.37E+02**
	Total incl. D	**2.00E+02**	**2.33E+02**	**1.46E+02**	**1.50E+02**	**1.75E+02**	**1.56E+02**	**1.19E+02**	**1.34E+02**	**1.56E+02**	**1.37E+02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	3.29E+00	5.11E+00	2.07E+01	6.42E+00	6.22E+00	4.02E+00	5.17E+00	4.91E+00	4.81E+00	6.43E+00
	A4-A5	2.55E+01	2.43E+01	6.54E+01	1.64E+01	1.27E+01	8.23E+00	3.12E+00	1.93E+00	1.43E+01	1.50E+01
	B2, B4	2.08E+02	2.39E+02	2.27E+02	2.07E+02	2.14E+02	1.64E+02	1.83E+02	1.47E+02	2.20E+02	1.46E+02
	B6	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
	B7	5.71E+00	7.01E+00	9.44E+00	8.66E+00	7.52E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
	C1-C4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.40E+02**	**2.74E+02**	**3.12E+02**	**2.29E+02**	**2.34E+02**	**1.82E+02**	**1.98E+02**	**1.58E+02**	**2.42E+02**	**1.71E+02**
	Total incl. D	**2.40E+02**	**2.74E+02**	**3.12E+02**	**2.29E+02**	**2.34E+02**	**1.82E+02**	**1.98E+02**	**1.58E+02**	**2.42E+02**	**1.71E+02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington											
Total Primary Energy (MJ) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
		60 Year									
	A1-A3	4.08E+05	5.72E+05	1.15E+06	2.18E+06	1.91E+06	1.60E+06	4.47E+06	2.85E+06	1.34E+06	4.32E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	5.60E+06	3.76E+06	2.95E+06	2.89E+06	1.19E+06	4.09E+06	1.07E+07
	B2, B4	5.98E+07	6.96E+07	3.39E+07	1.86E+08	1.68E+08	1.57E+08	4.39E+08	2.46E+08	1.51E+08	2.59E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.99E+05	7.20E+05	4.66E+05	2.75E+06	2.08E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.35E+07**	**7.34E+07**	**3.87E+07**	**1.93E+08**	**1.74E+08**	**1.63E+08**	**4.53E+08**	**2.54E+08**	**1.57E+08**	**2.77E+08**
	Total incl. D	**6.35E+07**	**7.34E+07**	**3.87E+07**	**1.93E+08**	**1.74E+08**	**1.63E+08**	**4.53E+08**	**2.54E+08**	**1.57E+08**	**2.77E+08**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	3.37E+00	4.93E+00	1.05E+01	4.67E+00	5.37E+00	4.17E+00	3.25E+00	4.38E+00	3.38E+00	5.43E+00
	A4-A5	2.38E+01	2.35E+01	3.42E+01	1.20E+01	1.06E+01	7.71E+00	2.10E+00	1.83E+00	1.03E+01	1.35E+01
	B2, B4	4.93E+02	6.00E+02	3.11E+02	3.97E+02	4.73E+02	4.10E+02	3.20E+02	3.78E+02	3.79E+02	3.26E+02
	B6	4.74E+00	4.83E+00	2.66E+00	3.71E+00	4.26E+00	4.86E+00	3.41E+00	4.81E+00	3.65E+00	4.55E+00
	B7	4.94E+00	6.21E+00	4.28E+00	5.88E+00	5.87E+00	4.91E+00	4.09E+00	5.00E+00	3.92E+00	6.00E+00
	C1-C4	-6.39E+00	-6.28E+00	-6.91E+00	-9.86E+00	-9.57E+00	-4.07E+00	-2.60E+00	-4.48E+00	-4.74E+00	-6.18E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.24E+02**	**6.33E+02**	**3.56E+02**	**4.14E+02**	**4.90E+02**	**4.27E+02**	**3.30E+02**	**3.89E+02**	**3.95E+02**	**3.49E+02**
	Total incl. D	**5.24E+02**	**6.33E+02**	**3.56E+02**	**4.14E+02**	**4.90E+02**	**4.27E+02**	**3.30E+02**	**3.89E+02**	**3.95E+02**	**3.49E+02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	4.04E+00	5.80E+00	2.25E+01	7.14E+00	7.17E+00	4.88E+00	5.43E+00	5.18E+00	5.26E+00	6.80E+00
	A4-A5	2.86E+01	2.77E+01	7.32E+01	1.83E+01	1.41E+01	9.02E+00	3.51E+00	2.16E+00	1.60E+01	1.69E+01
	B2, B4	5.92E+02	7.06E+02	6.66E+02	6.08E+02	6.31E+02	4.79E+02	5.33E+02	4.47E+02	5.90E+02	4.07E+02
	B6	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00
	B7	5.92E+00	7.31E+00	9.16E+00	9.00E+00	7.83E+00	5.75E+00	6.83E+00	5.91E+00	6.10E+00	7.51E+00
	C1-C4	-7.67E+00	-7.39E+00	-1.48E+01	-1.51E+01	-1.28E+01	-4.76E+00	-4.33E+00	-5.30E+00	-7.38E+00	-7.73E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.28E+02**	**7.45E+02**	**7.61E+02**	**6.33E+02**	**6.53E+02**	**5.00E+02**	**5.50E+02**	**4.61E+02**	**6.16E+02**	**4.36E+02**
	Total incl. D	**6.28E+02**	**7.45E+02**	**7.61E+02**	**6.33E+02**	**6.53E+02**	**5.00E+02**	**5.50E+02**	**4.61E+02**	**6.16E+02**	**4.36E+02**

Christchurch

Whole Building Life Cycle Assessment Reference Building Results for Christchurch

Climate Change (100 Year) Impact Potential (kg CO2 eq.)	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
						60 Year					
	A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
	A4-A5	31,485	34,067	80,034	152,420	124,488	88,316	296,226	189,682	97,478	277,253
	B2, B4	230,449	208,448	296,945	408,794	257,629	227,009	231,898	80,012	279,324	861,915
	B6	3,792,722	4,031,503	1,979,415	11,130,263	9,939,490	9,498,341	26,990,842	12,383,631	10,615,800	17,656,019
	B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
	C1-C4	42,229	57,336	35,933	172,229	136,692	145,193	312,731	185,085	97,008	280,688
	D	- 53,128	- 58,939	- 51,317	- 415,334	- 346,525	- 162,533	- 406,399	- 301,427	- 221,596	- 534,519
	Total excl. D	**4,573,869**	**4,704,534**	**2,811,033**	**14,663,003**	**12,795,830**	**10,869,962**	**33,520,244**	**16,193,594**	**12,702,419**	**24,130,979**
	Total incl. D	**4,520,740**	**4,645,595**	**2,759,715**	**14,247,670**	**12,449,305**	**10,707,429**	**33,113,844**	**15,892,168**	**12,480,824**	**23,596,460**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
	A4-A5	0.26	0.29	0.74	0.33	0.35	0.23	0.22	0.29	0.25	0.35
	B2, B4	1.90	1.80	2.73	0.87	0.73	0.59	0.17	0.12	0.70	1.08
	B6	31.28	34.76	18.19	23.82	28.03	24.84	19.63	19.00	26.71	22.21
	B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
	C1-C4	0.35	0.49	0.33	0.37	0.39	0.38	0.23	0.28	0.24	0.35
	D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.43	-0.30	-0.46	-0.56	-0.67
	Total excl. D	**37.72**	**40.56**	**25.83**	**31.38**	**36.08**	**28.43**	**24.38**	**24.84**	**31.96**	**30.36**
	Total incl. D	**37.28**	**40.06**	**25.36**	**30.49**	**35.10**	**28.00**	**24.09**	**24.38**	**31.40**	**29.69**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
	A4-A5	0.31	0.35	1.57	0.50	0.47	0.27	0.36	0.34	0.38	0.44
	B2, B4	2.28	2.12	5.84	1.34	0.97	0.69	0.28	0.15	1.09	1.36
	B6	37.54	40.92	38.90	36.46	37.39	29.07	32.76	22.48	41.57	27.78
	B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	C1-C4	0.42	0.58	0.71	0.56	0.51	0.44	0.38	0.34	0.38	0.44
	D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.50	-0.49	-0.55	-0.87	-0.84
	Total excl. D	**45.27**	**47.75**	**55.25**	**48.03**	**48.14**	**33.27**	**40.69**	**29.40**	**49.74**	**37.97**
	Total incl. D	**44.74**	**47.15**	**54.24**	**46.67**	**46.84**	**32.77**	**40.19**	**28.85**	**48.88**	**37.13**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch											
Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
	60 Year										
	A1-A3	4.01E-03	4.65E-03	1.17E-02	2.32E-02	1.98E-02	1.27E-02	4.66E-02	3.01E-02	1.38E-02	4.34E-02
	A4-A5	1.02E-02	8.72E-03	1.31E-02	2.21E-02	1.50E-02	7.86E-03	1.07E-02	5.25E-03	1.59E-02	3.96E-02
	B2, B4	4.79E-02	5.51E-02	2.64E-02	1.48E-01	1.33E-01	1.24E-01	3.47E-01	1.85E-01	1.21E-01	2.13E-01
	B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
	B7	6.52E-03	6.69E-03	5.52E-03	3.00E-02	2.15E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
	C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.09E-02**	**7.57E-02**	**5.76E-02**	**2.29E-01**	**1.92E-01**	**1.67E-01**	**4.86E-01**	**2.69E-01**	**1.72E-01**	**3.61E-01**
	Total incl. D	**7.09E-02**	**7.57E-02**	**5.76E-02**	**2.29E-01**	**1.92E-01**	**1.67E-01**	**4.86E-01**	**2.69E-01**	**1.72E-01**	**3.61E-01**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	3.31E-08	4.01E-08	1.07E-07	4.97E-08	5.58E-08	3.33E-08	3.39E-08	4.62E-08	3.46E-08	5.46E-08
	A4-A5	8.43E-08	7.52E-08	1.21E-07	4.72E-08	4.22E-08	2.06E-08	7.77E-09	8.05E-09	3.99E-08	4.99E-08
	B2, B4	3.95E-07	4.75E-07	2.43E-07	3.17E-07	3.75E-07	3.25E-07	2.52E-07	2.83E-07	3.06E-07	2.68E-07
	B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
	B7	5.38E-08	5.77E-08	5.07E-08	6.43E-08	6.05E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
	C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.85E-07**	**6.52E-07**	**5.29E-07**	**4.89E-07**	**5.43E-07**	**4.37E-07**	**3.54E-07**	**4.13E-07**	**4.32E-07**	**4.54E-07**
	Total incl. D	**5.85E-07**	**6.52E-07**	**5.29E-07**	**4.89E-07**	**5.43E-07**	**4.37E-07**	**3.54E-07**	**4.13E-07**	**4.32E-07**	**4.54E-07**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	3.97E-08	4.72E-08	2.30E-07	7.60E-08	7.45E-08	3.90E-08	5.66E-08	5.47E-08	5.39E-08	6.82E-08
	A4-A5	1.01E-07	8.86E-08	2.58E-07	7.23E-08	5.64E-08	2.41E-08	1.30E-08	9.53E-09	6.22E-08	6.24E-08
	B2, B4	4.74E-07	5.59E-07	5.19E-07	4.85E-07	5.00E-07	3.80E-07	4.21E-07	3.35E-07	4.76E-07	3.35E-07
	B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
	B7	6.46E-08	6.80E-08	1.09E-07	9.84E-08	8.08E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
	C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.01E-07**	**7.68E-07**	**1.13E-06**	**7.49E-07**	**7.24E-07**	**5.11E-07**	**5.90E-07**	**4.89E-07**	**6.72E-07**	**5.68E-07**
	Total incl. D	**7.01E-07**	**7.68E-07**	**1.13E-06**	**7.49E-07**	**7.24E-07**	**5.11E-07**	**5.90E-07**	**4.89E-07**	**6.72E-07**	**5.68E-07**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch

Acidification Impact Potential (kg SO2 eq.) Impact

Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
					60 Year					
A1-A3	2.94E+02	4.40E+02	1.06E+03	1.10E+03	1.09E+03	8.47E+02	1.93E+03	1.31E+03	7.89E+02	1.99E+03
A4-A5	4.58E-02	6.09E+01	3.83E-02	8.29E+01	8.79E+01	7.20E+00	1.50E-01	3.37E+01	1.19E+02	1.62E-01
B2, B4	1.43E+04	1.65E+04	7.89E+03	4.42E+04	3.97E+04	3.71E+04	1.04E+05	5.53E+04	3.62E+04	6.35E+04
B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
B7	7.55E+02	1.10E+03	9.86E+02	1.61E+03	1.77E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.56E+04**	**1.81E+04**	**9.96E+03**	**4.69E+04**	**4.25E+04**	**4.00E+04**	**1.10E+05**	**5.93E+04**	**3.84E+04**	**6.89E+04**
Total incl. D	**1.56E+04**	**1.81E+04**	**9.96E+03**	**4.69E+04**	**4.25E+04**	**4.00E+04**	**1.10E+05**	**5.93E+04**	**3.84E+04**	**6.89E+04**
Lifecycle Module Stage	**Z3, Co, S3a / m² GFA / year**	**Z3, Cx, S3 / m² GFA / year**	**Z3, Co, S3b / m² GFA / year**	**Z3, Co, S4a / m² GFA / year**	**Z3, Co, S4b / m² GFA / year**	**Z3, Cx, S4a / m² GFA / year**	**Z3, Cx, S5 / m² GFA / year**	**Z3, Co, S5a / m² GFA / year**	**Z3, Cx, S4b / m² GFA / year**	**Z3, Co, S5b / m² GFA / year**
A1-A3	2.43E-03	3.80E-03	9.70E-03	2.35E-03	3.06E-03	2.22E-03	1.40E-03	2.01E-03	1.99E-03	2.51E-03
A4-A5	3.77E-07	5.25E-04	3.52E-07	1.77E-04	2.48E-04	1.88E-05	1.09E-07	5.17E-05	3.00E-04	2.04E-07
B2, B4	1.18E-01	1.42E-01	7.25E-02	9.47E-02	1.12E-01	9.70E-02	7.54E-02	8.49E-02	9.10E-02	7.99E-02
B6	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
B7	6.23E-03	9.46E-03	9.06E-03	3.45E-03	4.98E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
C1-C4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.28E-01**	**1.56E-01**	**9.15E-02**	**1.00E-01**	**1.20E-01**	**1.05E-01**	**7.97E-02**	**9.09E-02**	**9.66E-02**	**8.67E-02**
Total incl. D	**1.28E-01**	**1.56E-01**	**9.15E-02**	**1.00E-01**	**1.20E-01**	**1.05E-01**	**7.97E-02**	**9.09E-02**	**9.66E-02**	**8.67E-02**
Lifecycle Module Stage	**Z3, Co, S3a / m² NLA / year**	**Z3, Cx, S3 / m² NLA / year**	**Z3, Co, S3b / m² NLA / year**	**Z3, Co, S4a / m² NLA / year**	**Z3, Co, S4b / m² NLA / year**	**Z3, Cx, S4a / m² NLA / year**	**Z3, Cx, S5 / m² NLA / year**	**Z3, Co, S5a / m² NLA / year**	**Z3, Cx, S4b / m² NLA / year**	**Z3, Co, S5b / m² NLA / year**
A1-A3	2.91E-03	4.47E-03	2.08E-02	3.60E-03	4.08E-03	2.59E-03	2.34E-03	2.38E-03	3.09E-03	3.14E-03
A4-A5	4.53E-07	6.18E-04	7.53E-07	2.72E-04	3.31E-04	2.20E-05	1.82E-07	6.12E-05	4.68E-04	2.55E-07
B2, B4	1.42E-01	1.67E-01	1.55E-01	1.45E-01	1.49E-01	1.13E-01	1.26E-01	1.00E-01	1.42E-01	1.00E-01
B6	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
B7	7.47E-03	1.11E-02	1.94E-02	5.29E-03	6.65E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
C1-C4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.54E-01**	**1.83E-01**	**1.96E-01**	**1.53E-01**	**1.60E-01**	**1.22E-01**	**1.33E-01**	**1.08E-01**	**1.50E-01**	**1.08E-01**
Total incl. D	**1.54E-01**	**1.83E-01**	**1.96E-01**	**1.53E-01**	**1.60E-01**	**1.22E-01**	**1.33E-01**	**1.08E-01**	**1.50E-01**	**1.08E-01**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch											
Eutrophication Impact Potential (kg PO4 $^{3-}$ eq.) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
		60 Year									
	A1-A3	6.65E+01	6.27E+01	1.50E+02	2.52E+02	2.16E+02	1.87E+02	4.72E+02	3.15E+02	1.74E+02	4.75E+02
	A4-A5	4.71E+02	3.55E+02	5.95E+02	8.44E+02	4.05E+02	6.77E-01	5.55E+02	1.87E+02	4.34E+02	2.05E+03
	B2, B4	6.77E+03	7.80E+03	3.74E+03	2.09E+04	1.88E+04	1.75E+04	4.90E+04	2.63E+04	1.71E+04	3.00E+04
	B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
	B7	1.84E+02	2.38E+02	2.40E+02	9.38E+02	7.13E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
	C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**8.57E+03**	**9.49E+03**	**5.24E+03**	**2.63E+04**	**2.30E+04**	**2.19E+04**	**5.98E+04**	**3.34E+04**	**2.12E+04**	**4.05E+04**
	Total incl. D	**8.57E+03**	**9.49E+03**	**5.24E+03**	**2.63E+04**	**2.30E+04**	**2.19E+04**	**5.98E+04**	**3.34E+04**	**2.12E+04**	**4.05E+04**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	5.48E-04	5.41E-04	1.38E-03	5.40E-04	6.10E-04	4.90E-04	3.43E-04	4.84E-04	4.38E-04	5.97E-04
	A4-A5	3.88E-03	3.06E-03	5.47E-03	1.81E-03	1.14E-03	1.77E-06	4.04E-04	2.87E-04	1.09E-03	2.58E-03
	B2, B4	5.58E-02	6.73E-02	3.43E-02	4.48E-02	5.30E-02	4.59E-02	3.57E-02	4.03E-02	4.29E-02	3.78E-02
	B6	9.46E-03	9.65E-03	5.31E-03	7.42E-03	8.51E-03	9.71E-03	6.81E-03	9.60E-03	7.30E-03	9.08E-03
	B7	1.52E-03	2.05E-03	2.20E-03	2.01E-03	2.01E-03	1.60E-03	5.82E-04	9.60E-04	2.12E-03	1.36E-03
	C1-C4	-5.15E-04	-7.41E-04	-5.85E-04	-3.67E-04	-4.80E-04	-4.08E-04	-2.57E-04	-3.41E-04	-4.49E-04	-4.67E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.07E-02**	**8.18E-02**	**4.81E-02**	**5.62E-02**	**6.48E-02**	**5.73E-02**	**4.35E-02**	**5.13E-02**	**5.34E-02**	**5.09E-02**
	Total incl. D	**7.07E-02**	**8.18E-02**	**4.81E-02**	**5.62E-02**	**6.48E-02**	**5.73E-02**	**4.35E-02**	**5.13E-02**	**5.34E-02**	**5.09E-02**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	6.58E-04	6.36E-04	2.95E-03	8.26E-04	8.14E-04	5.73E-04	5.73E-04	5.73E-04	6.82E-04	7.47E-04
	A4-A5	4.66E-03	3.60E-03	1.17E-02	2.76E-03	1.52E-03	2.07E-06	6.74E-04	3.40E-04	1.70E-03	3.22E-03
	B2, B4	6.70E-02	7.92E-02	7.35E-02	6.86E-02	7.08E-02	5.37E-02	5.95E-02	4.77E-02	6.68E-02	4.72E-02
	B6	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
	B7	1.82E-03	2.41E-03	4.71E-03	3.07E-03	2.68E-03	1.87E-03	9.70E-04	1.14E-03	3.30E-03	1.70E-03
	C1-C4	-6.18E-04	-8.72E-04	-1.25E-03	-5.62E-04	-6.41E-04	-4.78E-04	-4.30E-04	-4.03E-04	-6.99E-04	-5.84E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**8.49E-02**	**9.63E-02**	**1.03E-01**	**8.61E-02**	**8.65E-02**	**6.70E-02**	**7.26E-02**	**6.07E-02**	**8.32E-02**	**6.37E-02**
	Total incl. D	**8.49E-02**	**9.63E-02**	**1.03E-01**	**8.61E-02**	**8.65E-02**	**6.70E-02**	**7.26E-02**	**6.07E-02**	**8.32E-02**	**6.37E-02**

Tropospheric Ozone Formation Impact Potential (kg C_2H_2 eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Christchurch										
Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
60 Year										
A1-A3	3.14E+01	3.48E+01	8.54E+01	1.41E+02	1.19E+02	8.29E+01	2.70E+02	1.71E+02	8.73E+01	2.61E+02
A4-A5	6.33E+01	9.50E+01	9.07E+01	1.12E+02	1.72E+02	4.21E+02	1.50E-01	6.16E+00	1.82E+02	1.29E+01
B2, B4	9.03E+02	1.03E+03	4.95E+02	2.77E+03	2.49E+03	2.33E+03	6.52E+03	3.42E+03	2.31E+03	4.04E+03
B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
B7	4.91E+01	6.61E+01	5.47E+01	1.70E+02	1.39E+02	1.35E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.03E+03**	**1.21E+03**	**6.95E+02**	**3.05E+03**	**2.82E+03**	**2.98E+03**	**7.16E+03**	**3.80E+03**	**2.65E+03**	**4.53E+03**
Total incl. D	**1.03E+03**	**1.21E+03**	**6.95E+02**	**3.05E+03**	**2.82E+03**	**2.98E+03**	**7.16E+03**	**3.80E+03**	**2.65E+03**	**4.53E+03**
Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
A1-A3	2.59E-04	3.00E-04	7.85E-04	3.01E-04	3.37E-04	2.17E-04	1.97E-04	2.63E-04	2.20E-04	3.28E-04
A4-A5	5.22E-04	8.19E-04	8.33E-04	2.40E-04	4.86E-04	1.10E-03	1.09E-07	9.45E-06	4.58E-04	1.63E-05
B2, B4	7.45E-03	8.87E-03	4.55E-03	5.93E-03	7.02E-03	6.09E-03	4.75E-03	5.25E-03	5.82E-03	5.08E-03
B6	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
B7	4.05E-04	5.70E-04	5.03E-04	3.64E-04	3.93E-04	3.52E-04	2.46E-04	3.11E-04	2.69E-04	3.99E-04
C1-C4	-3.74E-04	-3.77E-04	-4.15E-04	-5.04E-04	-5.01E-04	-2.24E-04	-1.51E-04	-2.49E-04	-2.79E-04	-3.43E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**8.50E-03**	**1.04E-02**	**6.38E-03**	**6.52E-03**	**7.95E-03**	**7.78E-03**	**5.21E-03**	**5.82E-03**	**6.67E-03**	**5.70E-03**
Total incl. D	**8.50E-03**	**1.04E-02**	**6.38E-03**	**6.52E-03**	**7.95E-03**	**7.78E-03**	**5.21E-03**	**5.82E-03**	**6.67E-03**	**5.70E-03**
Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
A1-A3	3.11E-04	3.53E-04	1.68E-03	4.61E-04	4.49E-04	2.54E-04	3.28E-04	3.11E-04	3.42E-04	4.10E-04
A4-A5	6.27E-04	9.65E-04	1.78E-03	3.67E-04	6.48E-04	1.29E-03	1.82E-07	1.12E-05	7.12E-04	2.04E-05
B2, B4	8.94E-03	1.04E-02	9.72E-03	9.08E-03	9.36E-03	7.13E-03	7.92E-03	6.21E-03	9.06E-03	6.35E-03
B6	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
B7	4.86E-04	6.71E-04	1.08E-03	5.57E-04	5.24E-04	4.12E-04	4.10E-04	3.68E-04	4.19E-04	4.99E-04
C1-C4	-4.49E-04	-4.44E-04	-8.88E-04	-7.72E-04	-6.68E-04	-2.62E-04	-2.52E-04	-2.95E-04	-4.34E-04	-4.29E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.02E-02**	**1.23E-02**	**1.37E-02**	**9.98E-03**	**1.06E-02**	**9.11E-03**	**8.69E-03**	**6.89E-03**	**1.04E-02**	**7.13E-03**
Total incl. D	**1.02E-02**	**1.23E-02**	**1.37E-02**	**9.98E-03**	**1.06E-02**	**9.11E-03**	**8.69E-03**	**6.89E-03**	**1.04E-02**	**7.13E-03**

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Christchurch										
Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
60 Year										
A1-A3	2.74E+00	6.07E-02	2.94E+00	2.40E-01	2.36E-01	1.87E-01	3.90E-01	4.51E-01	1.29E+00	3.72E-01
A4-A5	4.67E-02	5.89E-02	3.95E-02	1.56E-01	1.63E-01	1.19E-01	1.51E-01	2.83E-02	1.65E-01	1.66E-01
B2, B4	7.85E+00	8.96E+00	4.31E+00	2.41E+01	2.17E+01	2.03E+01	5.67E+01	2.99E+01	2.01E+01	3.50E+01
B6	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
B7	3.71E-02	5.26E-02	2.53E-02	2.10E-01	1.99E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
C1-C4	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.39E+02**	**-1.12E+02**	**-1.63E+02**	**-2.38E+02**	**-1.55E+02**	**-3.80E+02**	**-9.42E+02**	**-5.96E+02**	**-2.60E+02**	**-8.82E+02**
Total incl. D	**-1.39E+02**	**-1.12E+02**	**-1.63E+02**	**-2.38E+02**	**-1.55E+02**	**-3.80E+02**	**-9.42E+02**	**-5.96E+02**	**-2.60E+02**	**-8.82E+02**
Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
A1-A3	2.26E-05	5.24E-07	2.70E-05	5.13E-07	6.65E-07	4.88E-07	2.84E-07	6.93E-07	3.25E-06	4.68E-07
A4-A5	3.85E-07	5.08E-07	3.63E-07	3.33E-07	4.59E-07	3.11E-07	1.10E-07	4.34E-08	4.15E-07	2.08E-07
B2, B4	6.47E-05	7.73E-05	3.96E-05	5.16E-05	6.11E-05	5.30E-05	4.13E-05	4.58E-05	5.05E-05	4.41E-05
B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.62E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.15E-03**	**-9.68E-04**	**-1.50E-03**	**-5.10E-04**	**-4.37E-04**	**-9.93E-04**	**-6.86E-04**	**-9.15E-04**	**-6.55E-04**	**-1.11E-03**
Total incl. D	**-1.15E-03**	**-9.68E-04**	**-1.50E-03**	**-5.10E-04**	**-4.37E-04**	**-9.93E-04**	**-6.86E-04**	**-9.15E-04**	**-6.55E-04**	**-1.11E-03**
Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
A1-A3	2.72E-05	6.17E-07	5.79E-05	7.85E-07	8.87E-07	5.71E-07	4.74E-07	8.20E-07	5.06E-06	5.85E-07
A4-A5	4.62E-07	5.98E-07	7.76E-07	5.10E-07	6.12E-07	3.64E-07	1.83E-07	5.14E-08	6.46E-07	2.61E-07
B2, B4	7.77E-05	9.10E-05	8.46E-05	7.91E-05	8.15E-05	6.20E-05	6.89E-05	5.42E-05	7.86E-05	5.51E-05
B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
B7	3.67E-07	5.34E-07	4.98E-07	6.87E-07	7.50E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.37E-03**	**-1.14E-03**	**-3.21E-03**	**-7.81E-04**	**-5.83E-04**	**-1.16E-03**	**-1.14E-03**	**-1.08E-03**	**-1.02E-03**	**-1.39E-03**
Total incl. D	**-1.37E-03**	**-1.14E-03**	**-3.21E-03**	**-7.81E-04**	**-5.83E-04**	**-1.16E-03**	**-1.14E-03**	**-1.08E-03**	**-1.02E-03**	**-1.39E-03**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
	60 Year										
	A1-A3	4.14E+05	4.73E+05	1.09E+06	2.20E+06	1.83E+06	1.42E+06	4.06E+06	2.67E+06	1.35E+06	3.92E+06
	A4-A5	2.58E+06	2.40E+06	3.33E+06	5.01E+06	3.38E+06	2.69E+06	2.57E+06	1.07E+06	3.66E+06	9.56E+06
	B2, B4	2.48E+07	2.71E+07	1.32E+07	7.41E+07	6.63E+07	6.29E+07	1.78E+08	8.58E+07	6.74E+07	1.14E+08
	B6	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	B7	5.77E+05	6.90E+05	4.80E+05	2.64E+06	1.92E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	C1-C4	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.82E+07**	**3.05E+07**	**1.76E+07**	**8.11E+07**	**7.17E+07**	**6.88E+07**	**1.90E+08**	**9.21E+07**	**7.34E+07**	**1.30E+08**
	Total incl. D	**2.82E+07**	**3.05E+07**	**1.76E+07**	**8.11E+07**	**7.17E+07**	**6.88E+07**	**1.90E+08**	**9.21E+07**	**7.34E+07**	**1.30E+08**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	3.42E+00	4.08E+00	1.00E+01	4.70E+00	5.17E+00	3.70E+00	2.95E+00	4.09E+00	3.41E+00	4.93E+00
	A4-A5	2.13E+01	2.07E+01	3.06E+01	1.07E+01	9.54E+00	7.04E+00	1.87E+00	1.63E+00	9.21E+00	1.20E+01
	B2, B4	2.05E+02	2.34E+02	1.21E+02	1.59E+02	1.87E+02	1.64E+02	1.29E+02	1.32E+02	1.70E+02	1.43E+02
	B6	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
	B7	4.76E+00	5.95E+00	4.41E+00	5.64E+00	5.41E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.79E+00
	C1-C4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.32E+02**	**2.63E+02**	**1.62E+02**	**1.74E+02**	**2.02E+02**	**1.80E+02**	**1.38E+02**	**1.41E+02**	**1.85E+02**	**1.64E+02**
	Total incl. D	**2.32E+02**	**2.63E+02**	**1.62E+02**	**1.74E+02**	**2.02E+02**	**1.80E+02**	**1.38E+02**	**1.41E+02**	**1.85E+02**	**1.64E+02**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	4.10E+00	4.80E+00	2.14E+01	7.20E+00	6.89E+00	4.33E+00	4.93E+00	4.84E+00	5.30E+00	6.17E+00
	A4-A5	2.55E+01	2.43E+01	6.54E+01	1.64E+01	1.27E+01	8.23E+00	3.12E+00	1.93E+00	1.43E+01	1.50E+01
	B2, B4	2.46E+02	2.75E+02	2.59E+02	2.43E+02	2.49E+02	1.92E+02	2.16E+02	1.56E+02	2.64E+02	1.79E+02
	B6	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
	B7	5.71E+00	7.01E+00	9.44E+00	8.63E+00	7.22E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
	C1-C4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.79E+02**	**3.10E+02**	**3.46E+02**	**2.66E+02**	**2.70E+02**	**2.11E+02**	**2.30E+02**	**1.67E+02**	**2.87E+02**	**2.05E+02**
	Total incl. D	**2.79E+02**	**3.10E+02**	**3.46E+02**	**2.66E+02**	**2.70E+02**	**2.11E+02**	**2.30E+02**	**1.67E+02**	**2.87E+02**	**2.05E+02**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch											
Total Primary Energy (MJ) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
	60 Year										
	A1-A3	4.93E+05	5.38E+05	1.18E+06	2.43E+06	2.09E+06	1.69E+06	4.26E+06	2.81E+06	1.47E+06	4.13E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	5.60E+06	3.76E+06	2.95E+06	2.89E+06	1.19E+06	4.09E+06	1.07E+07
	B2, B4	6.82E+07	7.72E+07	3.72E+07	2.08E+08	1.87E+08	1.75E+08	4.92E+08	2.55E+08	1.76E+08	3.06E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.99E+05	7.20E+05	4.66E+05	2.74E+06	2.00E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.19E+07**	**8.10E+07**	**4.21E+07**	**2.16E+08**	**1.93E+08**	**1.82E+08**	**5.06E+08**	**2.63E+08**	**1.83E+08**	**3.24E+08**
	Total incl. D	**7.19E+07**	**8.10E+07**	**4.21E+07**	**2.16E+08**	**1.93E+08**	**1.82E+08**	**5.06E+08**	**2.63E+08**	**1.83E+08**	**3.24E+08**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	4.06E+00	4.64E+00	1.09E+01	5.19E+00	5.90E+00	4.41E+00	3.10E+00	4.31E+00	3.70E+00	5.20E+00
	A4-A5	2.38E+01	2.35E+01	3.42E+01	1.20E+01	1.06E+01	7.71E+00	2.10E+00	1.83E+00	1.03E+01	1.35E+01
	B2, B4	5.62E+02	6.66E+02	3.42E+02	4.46E+02	5.27E+02	4.59E+02	3.58E+02	3.91E+02	4.43E+02	3.85E+02
	B6	4.74E+00	4.83E+00	2.66E+00	3.71E+00	4.26E+00	4.86E+00	3.41E+00	4.81E+00	3.65E+00	4.55E+00
	B7	4.94E+00	6.21E+00	4.28E+00	5.86E+00	5.63E+00	4.91E+00	4.09E+00	5.00E+00	3.92E+00	6.00E+00
	C1-C4	-6.39E+00	-6.28E+00	-6.91E+00	-9.86E+00	-9.57E+00	-4.07E+00	-2.60E+00	-4.48E+00	-4.74E+00	-6.18E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.93E+02**	**6.99E+02**	**3.87E+02**	**4.63E+02**	**5.44E+02**	**4.76E+02**	**3.68E+02**	**4.03E+02**	**4.60E+02**	**4.08E+02**
	Total incl. D	**5.93E+02**	**6.99E+02**	**3.87E+02**	**4.63E+02**	**5.44E+02**	**4.76E+02**	**3.68E+02**	**4.03E+02**	**4.60E+02**	**4.08E+02**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	4.88E+00	5.46E+00	2.33E+01	7.95E+00	7.87E+00	5.16E+00	5.17E+00	5.10E+00	5.76E+00	6.50E+00
	A4-A5	2.86E+01	2.77E+01	7.32E+01	1.83E+01	1.41E+01	9.02E+00	3.51E+00	2.16E+00	1.60E+01	1.69E+01
	B2, B4	6.75E+02	7.84E+02	7.31E+02	6.83E+02	7.04E+02	5.37E+02	5.97E+02	4.63E+02	6.89E+02	4.81E+02
	B6	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00
	B7	5.92E+00	7.31E+00	9.16E+00	8.97E+00	7.52E+00	5.75E+00	6.83E+00	5.91E+00	6.10E+00	7.51E+00
	C1-C4	-7.67E+00	-7.39E+00	-1.48E+01	-1.51E+01	-1.28E+01	-4.76E+00	-4.33E+00	-5.30E+00	-7.38E+00	-7.73E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**7.12E+02**	**8.22E+02**	**8.27E+02**	**7.09E+02**	**7.26E+02**	**5.58E+02**	**6.14E+02**	**4.77E+02**	**7.16E+02**	**5.10E+02**
	Total incl. D	**7.12E+02**	**8.22E+02**	**8.27E+02**	**7.09E+02**	**7.26E+02**	**5.58E+02**	**6.14E+02**	**4.77E+02**	**7.16E+02**	**5.10E+02**

F2. Reference office building total impacts and impacts by GFA and NLA (without plug loads in module B6)

Auckland

Climate Change (100 Year) Impact Potential (kg CO_2 eq.)

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads										
Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
60 Year										
A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
A4-A5	24,840	35,777	67,207	122,997	99,748	85,948	266,622	163,173	81,887	244,238
B2, B4	230,449	208,448	296,945	392,205	240,036	226,909	231,898	73,266	261,319	861,915
B6	1,843,639	2,438,502	1,071,733	6,000,682	5,952,404	5,242,133	15,881,702	8,857,441	4,333,912	8,309,314
B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
C1-C4	42,173	57,332	35,933	172,228	136,692	145,193	312,731	185,085	97,008	280,681
D	- 53,128	- 58,939	- 51,317	- 415,334	- 346,525	- 160,430	- 406,399	- 301,427	- 221,596	- 534,519
Total excl. D	**2,618,083**	**3,113,239**	**1,890,525**	**9,487,410**	**8,766,410**	**6,611,286**	**22,381,499**	**12,634,149**	**6,386,936**	**14,751,252**
Total incl. D	**2,564,955**	**3,054,301**	**1,839,207**	**9,072,076**	**8,419,885**	**6,450,856**	**21,975,100**	**12,332,723**	**6,165,341**	**14,216,733**
Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
A4-A5	0.20	0.31	0.62	0.26	0.28	0.22	0.19	0.25	0.21	0.31
B2, B4	1.90	1.80	2.73	0.84	0.68	0.59	0.17	0.11	0.66	1.08
B6	15.20	21.03	9.85	12.84	16.78	13.71	11.55	13.59	10.90	10.45
B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
C1-C4	0.35	0.49	0.33	0.37	0.39	0.38	0.23	0.28	0.24	0.35
D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.42	-0.30	-0.46	-0.56	-0.67
Total excl. D	**21.59**	**26.84**	**17.37**	**20.30**	**24.72**	**17.29**	**16.28**	**19.38**	**16.07**	**18.56**
Total incl. D	**21.15**	**26.33**	**16.90**	**19.41**	**23.74**	**16.87**	**15.99**	**18.92**	**15.51**	**17.89**
Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
A4-A5	0.25	0.36	1.32	0.40	0.38	0.26	0.32	0.30	0.32	0.38
B2, B4	2.28	2.12	5.84	1.28	0.90	0.69	0.28	0.13	1.02	1.36
B6	18.25	24.75	21.06	19.66	22.39	16.04	19.28	16.08	16.97	13.07
B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
C1-C4	0.42	0.58	0.71	0.56	0.51	0.44	0.38	0.34	0.38	0.44
D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.49	-0.49	-0.55	-0.87	-0.84
Total excl. D	**25.91**	**31.60**	**37.16**	**31.08**	**32.98**	**20.23**	**27.17**	**22.94**	**25.01**	**23.21**
Total incl. D	**25.39**	**31.00**	**36.15**	**29.72**	**31.68**	**19.74**	**26.67**	**22.39**	**24.14**	**22.37**

Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads										
Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
60 Year										
A1-A3	2.75E-03	4.99E-03	9.37E-03	1.76E-02	1.51E-02	1.23E-02	4.10E-02	2.51E-02	1.08E-02	3.71E-02
A4-A5	1.02E-02	8.72E-03	1.31E-02	1.75E-02	1.01E-02	7.83E-03	1.07E-02	3.38E-03	1.09E-02	3.96E-02
B2, B4	2.90E-02	3.93E-02	1.69E-02	9.69E-02	9.39E-02	8.23E-02	2.49E-01	1.43E-01	6.39E-02	1.31E-01
B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
B7	6.52E-03	6.69E-03	5.52E-03	3.00E-02	2.15E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**5.07E-02**	**6.02E-02**	**4.57E-02**	**1.67E-01**	**1.44E-01**	**1.25E-01**	**3.83E-01**	**2.20E-01**	**1.06E-01**	**2.73E-01**
Total incl. D	**5.07E-02**	**6.02E-02**	**4.57E-02**	**1.67E-01**	**1.44E-01**	**1.25E-01**	**3.83E-01**	**2.20E-01**	**1.06E-01**	**2.73E-01**
Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
A1-A3	2.27E-08	4.30E-08	8.61E-08	3.77E-08	4.26E-08	3.22E-08	2.98E-08	3.85E-08	2.72E-08	4.67E-08
A4-A5	8.43E-08	7.52E-08	1.21E-07	3.74E-08	2.85E-08	2.05E-08	7.77E-09	5.18E-09	2.74E-08	4.99E-08
B2, B4	2.39E-07	3.39E-07	1.55E-07	2.07E-07	2.65E-07	2.15E-07	1.81E-07	2.19E-07	1.61E-07	1.65E-07
B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
B7	5.38E-08	5.77E-08	5.07E-08	6.43E-08	6.05E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**4.18E-07**	**5.19E-07**	**4.20E-07**	**3.58E-07**	**4.06E-07**	**3.26E-07**	**2.79E-07**	**3.38E-07**	**2.67E-07**	**3.43E-07**
Total incl. D	**4.18E-07**	**5.19E-07**	**4.20E-07**	**3.58E-07**	**4.06E-07**	**3.26E-07**	**2.79E-07**	**3.38E-07**	**2.67E-07**	**3.43E-07**
Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
A1-A3	2.73E-08	5.07E-08	1.84E-07	5.78E-08	5.69E-08	3.76E-08	4.97E-08	4.55E-08	4.23E-08	5.84E-08
A4-A5	1.01E-07	8.86E-08	2.58E-07	5.72E-08	3.80E-08	2.40E-08	1.30E-08	6.13E-09	4.26E-08	6.24E-08
B2, B4	2.87E-07	3.99E-07	3.32E-07	3.18E-07	3.53E-07	2.52E-07	3.03E-07	2.59E-07	2.50E-07	2.07E-07
B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
B7	6.45E-08	6.80E-08	1.09E-07	9.84E-08	8.08E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**5.02E-07**	**6.12E-07**	**8.99E-07**	**5.48E-07**	**5.41E-07**	**3.82E-07**	**4.65E-07**	**4.00E-07**	**4.15E-07**	**4.29E-07**
Total incl. D	**5.02E-07**	**6.12E-07**	**8.99E-07**	**5.48E-07**	**5.41E-07**	**3.82E-07**	**4.65E-07**	**4.00E-07**	**4.15E-07**	**4.29E-07**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads

Acidification Impact Potential (kg SO2 eq.) Impact

Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
					60 Year					
A1-A3	2.67E+02	4.47E+02	1.00E+03	9.76E+02	9.81E+02	8.37E+02	1.81E+03	1.20E+03	7.24E+02	1.85E+03
A4-A5	4.58E-02	6.09E+01	3.83E-02	8.53E-02	8.87E-02	6.70E+00	1.50E-01	0.00E+00	2.95E+01	1.62E-01
B2, B4	8.71E+03	1.18E+04	5.07E+03	2.91E+04	2.82E+04	2.47E+04	7.48E+04	4.29E+04	1.92E+04	3.94E+04
B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
B7	7.55E+02	1.10E+03	9.86E+02	1.61E+03	1.77E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**9.93E+03**	**1.34E+04**	**7.08E+03**	**3.15E+04**	**3.08E+04**	**2.76E+04**	**8.07E+04**	**4.66E+04**	**2.12E+04**	**4.46E+04**
Total incl. D	**9.93E+03**	**1.34E+04**	**7.08E+03**	**3.15E+04**	**3.08E+04**	**2.76E+04**	**8.07E+04**	**4.66E+04**	**2.12E+04**	**4.46E+04**
Lifecycle Module Stage	**Z1, Co, S3a / m² GFA / year**	**Z1, Cx, S3 / m² GFA / year**	**Z1, Co, S3b / m² GFA / year**	**Z1, Co, S4a / m² GFA / year**	**Z1, Co, S4b / m² GFA / year**	**Z1, Cx, S4a / m² GFA / year**	**Z1, Cx, S5 / m² GFA / year**	**Z1, Co, S5a / m² GFA / year**	**Z1, Cx, S4b / m² GFA / year**	**Z1, Co, S5b / m² GFA / year**
A1-A3	2.20E-03	3.86E-03	9.21E-03	2.09E-03	2.77E-03	2.19E-03	1.31E-03	1.84E-03	1.82E-03	2.33E-03
A4-A5	3.77E-07	5.25E-04	3.52E-07	1.82E-07	2.50E-07	1.75E-05	1.09E-07	0.00E+00	7.42E-05	2.04E-07
B2, B4	7.18E-02	1.02E-01	4.66E-02	6.23E-02	7.94E-02	6.46E-02	5.44E-02	6.58E-02	4.82E-02	4.96E-02
B6	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
B7	6.23E-03	9.46E-03	9.06E-03	3.45E-03	4.98E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
C1-C4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**8.19E-02**	**1.15E-01**	**6.51E-02**	**6.74E-02**	**8.68E-02**	**7.22E-02**	**5.87E-02**	**7.16E-02**	**5.34E-02**	**5.62E-02**
Total incl. D	**8.19E-02**	**1.15E-01**	**6.51E-02**	**6.74E-02**	**8.68E-02**	**7.22E-02**	**5.87E-02**	**7.16E-02**	**5.34E-02**	**5.62E-02**
Lifecycle Module Stage	**Z1, Co, S3a / m² NLA / year**	**Z1, Cx, S3 / m² NLA / year**	**Z1, Co, S3b / m² NLA / year**	**Z1, Co, S4a / m² NLA / year**	**Z1, Co, S4b / m² NLA / year**	**Z1, Cx, S4a / m² NLA / year**	**Z1, Cx, S5 / m² NLA / year**	**Z1, Co, S5a / m² NLA / year**	**Z1, Cx, S4b / m² NLA / year**	**Z1, Co, S5b / m² NLA / year**
A1-A3	2.64E-03	4.54E-03	1.97E-02	3.20E-03	3.69E-03	2.56E-03	2.19E-03	2.18E-03	2.83E-03	2.92E-03
A4-A5	4.53E-07	6.18E-04	7.53E-07	2.79E-07	3.34E-07	2.05E-05	1.82E-07	0.00E+00	1.16E-04	2.55E-07
B2, B4	8.62E-02	1.20E-01	9.97E-02	9.53E-02	1.06E-01	7.55E-02	9.08E-02	7.79E-02	7.50E-02	6.21E-02
B6	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
B7	7.47E-03	1.11E-02	1.94E-02	5.29E-03	6.65E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
C1-C4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**9.83E-02**	**1.36E-01**	**1.39E-01**	**1.03E-01**	**1.16E-01**	**8.44E-02**	**9.80E-02**	**8.47E-02**	**8.31E-02**	**7.03E-02**
Total incl. D	**9.83E-02**	**1.36E-01**	**1.39E-01**	**1.03E-01**	**1.16E-01**	**8.44E-02**	**9.80E-02**	**8.47E-02**	**8.31E-02**	**7.03E-02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads											
Eutrophication Impact Potential (kg PO4 $^{3-}$ eq.) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
	60 Year										
	A1-A3	5.90E+01	6.46E+01	1.35E+02	2.19E+02	1.87E+02	1.85E+02	4.38E+02	2.85E+02	1.57E+02	4.37E+02
	A4-A5	4.71E+02	3.55E+02	5.95E+02	8.15E+02	3.74E+02	5.04E-01	5.55E+02	1.76E+02	4.03E+02	2.05E+03
	B2, B4	4.14E+03	5.61E+03	2.41E+03	1.38E+04	1.34E+04	1.17E+04	3.55E+04	2.04E+04	9.08E+03	1.87E+04
	B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
	B7	1.76E+02	2.37E+02	2.40E+02	9.38E+02	7.12E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
	C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.93E+03**	**7.30E+03**	**3.89E+03**	**1.91E+04**	**1.75E+04**	**1.61E+04**	**4.63E+04**	**2.75E+04**	**1.32E+04**	**2.91E+04**
	Total incl. D	**5.93E+03**	**7.30E+03**	**3.89E+03**	**1.91E+04**	**1.75E+04**	**1.61E+04**	**4.63E+04**	**2.75E+04**	**1.32E+04**	**2.91E+04**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	4.86E-04	5.57E-04	1.24E-03	4.68E-04	5.27E-04	4.83E-04	3.19E-04	4.37E-04	3.94E-04	5.50E-04
	A4-A5	3.88E-03	3.06E-03	5.47E-03	1.74E-03	1.06E-03	1.32E-06	4.04E-04	2.69E-04	1.01E-03	2.58E-03
	B2, B4	3.41E-02	4.84E-02	2.21E-02	2.96E-02	3.77E-02	3.07E-02	2.58E-02	3.13E-02	2.29E-02	2.36E-02
	B6	9.46E-03	9.65E-03	5.31E-03	7.42E-03	8.51E-03	9.71E-03	6.81E-03	9.60E-03	7.30E-03	9.08E-03
	B7	1.45E-03	2.04E-03	2.20E-03	2.01E-03	2.01E-03	1.60E-03	5.82E-04	9.60E-04	2.12E-03	1.36E-03
	C1-C4	-5.15E-04	-7.41E-04	-5.85E-04	-3.67E-04	-4.80E-04	-4.08E-04	-2.57E-04	-3.41E-04	-4.49E-04	-4.67E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.89E-02**	**6.29E-02**	**3.58E-02**	**4.09E-02**	**4.93E-02**	**4.20E-02**	**3.37E-02**	**4.22E-02**	**3.32E-02**	**3.67E-02**
	Total incl. D	**4.89E-02**	**6.29E-02**	**3.58E-02**	**4.09E-02**	**4.93E-02**	**4.20E-02**	**3.37E-02**	**4.22E-02**	**3.32E-02**	**3.67E-02**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	5.84E-04	6.56E-04	2.66E-03	7.17E-04	7.03E-04	5.65E-04	5.32E-04	5.17E-04	6.13E-04	6.88E-04
	A4-A5	4.66E-03	3.60E-03	1.17E-02	2.67E-03	1.41E-03	1.54E-06	6.74E-04	3.19E-04	1.58E-03	3.22E-03
	B2, B4	4.09E-02	5.69E-02	4.73E-02	4.53E-02	5.03E-02	3.59E-02	4.31E-02	3.70E-02	3.56E-02	2.95E-02
	B6	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
	B7	1.74E-03	2.41E-03	4.71E-03	3.07E-03	2.68E-03	1.87E-03	9.70E-04	1.14E-03	3.30E-03	1.70E-03
	C1-C4	-6.18E-04	-8.72E-04	-1.25E-03	-5.62E-04	-6.41E-04	-4.78E-04	-4.30E-04	-4.03E-04	-6.99E-04	-5.84E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.86E-02**	**7.41E-02**	**7.65E-02**	**6.26E-02**	**6.58E-02**	**4.92E-02**	**5.62E-02**	**4.99E-02**	**5.17E-02**	**4.59E-02**
	Total incl. D	**5.86E-02**	**7.41E-02**	**7.65E-02**	**6.26E-02**	**6.58E-02**	**4.92E-02**	**5.62E-02**	**4.99E-02**	**5.17E-02**	**4.59E-02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads											
Tropospheric Ozone Formation Impact Potential (kg C2H2 eq.) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
		60 Year									
	A1-A3	2.68E+01	4.88E+01	7.69E+01	1.20E+02	1.02E+02	1.06E+02	2.50E+02	1.53E+02	7.65E+01	2.38E+02
	A4-A5	6.33E+01	9.50E+01	9.07E+01	9.69E+01	1.56E+02	4.21E+02	1.50E-01	0.00E+00	1.65E+02	1.29E+01
	B2, B4	5.35E+02	7.24E+02	3.12E+02	1.78E+03	1.73E+03	1.52E+03	4.60E+03	2.63E+03	1.19E+03	2.42E+03
	B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
	B7	4.91E+01	4.10E+02	5.47E+01	1.70E+02	1.39E+02	8.05E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
	C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.58E+02**	**1.26E+03**	**5.03E+02**	**2.02E+03**	**2.03E+03**	**2.86E+03**	**5.22E+03**	**2.98E+03**	**1.50E+03**	**2.90E+03**
	Total incl. D	**6.58E+02**	**1.26E+03**	**5.03E+02**	**2.02E+03**	**2.03E+03**	**2.86E+03**	**5.22E+03**	**2.98E+03**	**1.50E+03**	**2.90E+03**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	2.21E-04	4.21E-04	7.07E-04	2.58E-04	2.88E-04	2.78E-04	1.82E-04	2.35E-04	1.92E-04	2.99E-04
	A4-A5	5.22E-04	8.19E-04	8.33E-04	2.07E-04	4.41E-04	1.10E-03	1.09E-07	0.00E+00	4.16E-04	1.63E-05
	B2, B4	4.41E-03	6.24E-03	2.86E-03	3.82E-03	4.88E-03	3.97E-03	3.35E-03	4.03E-03	2.98E-03	3.05E-03
	B6	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
	B7	4.05E-04	3.54E-03	5.03E-04	3.64E-04	3.93E-04	2.10E-03	2.46E-04	3.11E-04	2.69E-04	3.99E-04
	C1-C4	-3.74E-04	-3.77E-04	-4.15E-04	-5.04E-04	-5.01E-04	-2.24E-04	-1.51E-04	-2.49E-04	-2.79E-04	-3.43E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.43E-03**	**1.09E-02**	**4.62E-03**	**4.33E-03**	**5.71E-03**	**7.47E-03**	**3.79E-03**	**4.57E-03**	**3.77E-03**	**3.65E-03**
	Total incl. D	**5.43E-03**	**1.09E-02**	**4.62E-03**	**4.33E-03**	**5.71E-03**	**7.47E-03**	**3.79E-03**	**4.57E-03**	**3.77E-03**	**3.65E-03**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	2.66E-04	4.96E-04	1.51E-03	3.94E-04	3.85E-04	3.25E-04	3.03E-04	2.78E-04	3.00E-04	3.74E-04
	A4-A5	6.27E-04	9.65E-04	1.78E-03	3.18E-04	5.88E-04	1.29E-03	1.82E-07	0.00E+00	6.48E-04	2.04E-05
	B2, B4	5.30E-03	7.35E-03	6.13E-03	5.84E-03	6.51E-03	4.64E-03	5.58E-03	4.77E-03	4.64E-03	3.81E-03
	B6	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
	B7	4.86E-04	4.16E-03	1.08E-03	5.57E-04	5.24E-04	2.46E-03	4.10E-04	3.68E-04	4.19E-04	4.99E-04
	C1-C4	-4.49E-04	-4.44E-04	-8.88E-04	-7.72E-04	-6.68E-04	-2.62E-04	-2.52E-04	-2.95E-04	-4.34E-04	-4.29E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.51E-03**	**1.28E-02**	**9.89E-03**	**6.63E-03**	**7.62E-03**	**8.74E-03**	**6.33E-03**	**5.41E-03**	**5.86E-03**	**4.56E-03**
	Total incl. D	**6.51E-03**	**1.28E-02**	**9.89E-03**	**6.63E-03**	**7.62E-03**	**8.74E-03**	**6.33E-03**	**5.41E-03**	**5.86E-03**	**4.56E-03**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
60 Year										
A1-A3	2.73E+00	6.47E-02	2.92E+00	1.72E-01	1.79E-01	1.81E-01	3.22E-01	3.91E-01	1.26E+00	2.96E-01
A4-A5	4.67E-02	5.89E-02	3.95E-02	8.68E-02	8.96E-02	1.18E-01	1.51E-01	3.02E-04	9.01E-02	1.66E-01
B2, B4	4.67E+00	6.32E+00	2.72E+00	1.56E+01	1.51E+01	1.33E+01	4.02E+01	2.30E+01	1.03E+01	2.12E+01
B6	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
B7	3.71E-02	5.26E-02	2.53E-02	2.10E-01	1.99E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
C1-C4	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.42E+02**	**-1.15E+02**	**-1.65E+02**	**-2.47E+02**	**-1.62E+02**	**-3.87E+02**	**-9.59E+02**	**-6.03E+02**	**-2.70E+02**	**-8.96E+02**
Total incl. D	**-1.42E+02**	**-1.15E+02**	**-1.65E+02**	**-2.47E+02**	**-1.62E+02**	**-3.87E+02**	**-9.59E+02**	**-6.03E+02**	**-2.70E+02**	**-8.96E+02**
Lifecycle Module Stage	**Z1, Co, S3a / m² GFA / year**	**Z1, Cx, S3 / m² GFA / year**	**Z1, Co, S3b / m² GFA / year**	**Z1, Co, S4a / m² GFA / year**	**Z1, Co, S4b / m² GFA / year**	**Z1, Cx, S4a / m² GFA / year**	**Z1, Cx, S5 / m² GFA / year**	**Z1, Co, S5a / m² GFA / year**	**Z1, Cx, S4b / m² GFA / year**	**Z1, Co, S5b / m² GFA / year**
A1-A3	2.25E-05	5.58E-07	2.68E-05	3.69E-07	5.05E-07	4.73E-07	2.34E-07	5.99E-07	3.16E-06	3.73E-07
A4-A5	3.85E-07	5.08E-07	3.63E-07	1.86E-07	2.53E-07	3.10E-07	1.10E-07	4.63E-10	2.27E-07	2.08E-07
B2, B4	3.85E-05	5.45E-05	2.50E-05	3.33E-05	4.26E-05	3.47E-05	2.92E-05	3.52E-05	2.60E-05	2.66E-05
B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.62E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.17E-03**	**-9.91E-04**	**-1.52E-03**	**-5.29E-04**	**-4.55E-04**	**-1.01E-03**	**-6.98E-04**	**-9.26E-04**	**-6.80E-04**	**-1.13E-03**
Total incl. D	**-1.17E-03**	**-9.91E-04**	**-1.52E-03**	**-5.29E-04**	**-4.55E-04**	**-1.01E-03**	**-6.98E-04**	**-9.26E-04**	**-6.80E-04**	**-1.13E-03**
Lifecycle Module Stage	**Z1, Co, S3a / m² NLA / year**	**Z1, Cx, S3 / m² NLA / year**	**Z1, Co, S3b / m² NLA / year**	**Z1, Co, S4a / m² NLA / year**	**Z1, Co, S4b / m² NLA / year**	**Z1, Cx, S4a / m² NLA / year**	**Z1, Cx, S5 / m² NLA / year**	**Z1, Co, S5a / m² NLA / year**	**Z1, Cx, S4b / m² NLA / year**	**Z1, Co, S5b / m² NLA / year**
A1-A3	2.70E-05	6.57E-07	5.74E-05	5.64E-07	6.74E-07	5.54E-07	3.91E-07	7.09E-07	4.92E-06	4.66E-07
A4-A5	4.62E-07	5.98E-07	7.76E-07	2.84E-07	3.37E-07	3.63E-07	1.83E-07	5.47E-10	3.53E-07	2.61E-07
B2, B4	4.63E-05	6.42E-05	5.35E-05	5.11E-05	5.69E-05	4.06E-05	4.88E-05	4.17E-05	4.05E-05	3.33E-05
B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
B7	3.67E-07	5.34E-07	4.98E-07	6.87E-07	7.50E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.41E-03**	**-1.17E-03**	**-3.24E-03**	**-8.09E-04**	**-6.08E-04**	**-1.18E-03**	**-1.16E-03**	**-1.10E-03**	**-1.06E-03**	**-1.41E-03**
Total incl. D	**-1.41E-03**	**-1.17E-03**	**-3.24E-03**	**-8.09E-04**	**-6.08E-04**	**-1.18E-03**	**-1.16E-03**	**-1.10E-03**	**-1.06E-03**	**-1.41E-03**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
						60 Year					
	A4-A5	3.14E+05	5.00E+05	8.96E+05	1.74E+06	1.45E+06	1.38E+06	3.60E+06	2.25E+06	1.11E+06	3.40E+06
	B2, B4	2.58E+06	2.40E+06	3.33E+06	4.39E+06	2.72E+06	2.69E+06	2.57E+06	8.12E+05	2.99E+06	9.56E+06
	B6	1.30E+07	1.74E+07	7.58E+06	4.28E+07	4.21E+07	3.70E+07	1.12E+08	6.31E+07	2.99E+07	5.88E+07
	B7	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	C1-C4	5.77E+05	6.90E+05	4.80E+05	2.64E+06	1.92E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	D	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.62E+07**	**2.08E+07**	**1.18E+07**	**4.87E+07**	**4.65E+07**	**4.29E+07**	**1.24E+08**	**6.88E+07**	**3.49E+07**	**7.44E+07**
	Total incl. D	**1.62E+07**	**2.08E+07**	**1.18E+07**	**4.87E+07**	**4.65E+07**	**4.29E+07**	**1.24E+08**	**6.88E+07**	**3.49E+07**	**7.44E+07**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	2.59E+00	4.31E+00	8.23E+00	3.72E+00	4.08E+00	3.60E+00	2.62E+00	3.45E+00	2.79E+00	4.28E+00
	A4-A5	2.13E+01	2.07E+01	3.06E+01	9.38E+00	7.68E+00	7.03E+00	1.87E+00	1.25E+00	7.51E+00	1.20E+01
	B2, B4	1.07E+02	1.50E+02	6.96E+01	9.16E+01	1.19E+02	9.67E+01	8.15E+01	9.68E+01	7.52E+01	7.40E+01
	B6	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
	B7	4.76E+00	5.95E+00	4.41E+00	5.64E+00	5.41E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.78E+00
	C1-C4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.34E+02**	**1.80E+02**	**1.08E+02**	**1.04E+02**	**1.31E+02**	**1.12E+02**	**9.00E+01**	**1.06E+02**	**8.79E+01**	**9.37E+01**
	Total incl. D	**1.34E+02**	**1.80E+02**	**1.08E+02**	**1.04E+02**	**1.31E+02**	**1.12E+02**	**9.00E+01**	**1.06E+02**	**8.79E+01**	**9.37E+01**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	3.10E+00	5.08E+00	1.76E+01	5.69E+00	5.44E+00	4.21E+00	4.36E+00	4.09E+00	4.35E+00	5.35E+00
	A4-A5	2.55E+01	2.43E+01	6.54E+01	1.44E+01	1.02E+01	8.22E+00	3.12E+00	1.47E+00	1.17E+01	1.50E+01
	B2, B4	1.29E+02	1.76E+02	1.49E+02	1.40E+02	1.58E+02	1.13E+02	1.36E+02	1.15E+02	1.17E+02	9.25E+01
	B6	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
	B7	5.71E+00	7.01E+00	9.44E+00	8.63E+00	7.22E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
	C1-C4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.61E+02**	**2.11E+02**	**2.32E+02**	**1.60E+02**	**1.75E+02**	**1.31E+02**	**1.50E+02**	**1.25E+02**	**1.37E+02**	**1.17E+02**
	Total incl. D	**1.61E+02**	**2.11E+02**	**2.32E+02**	**1.60E+02**	**1.75E+02**	**1.31E+02**	**1.50E+02**	**1.25E+02**	**1.37E+02**	**1.17E+02**

Whole Building Life Cycle Assessment Reference Building Results for Auckland Excluding B6 Plug Loads											
Total Primary Energy (MJ) Impact	Lifecycle Module Stage	Z1, Co, S3a	Z1, Cx, S3	Z1, Co, S3b	Z1, Co, S4a	Z1, Co, S4b	Z1, Cx, S4a	Z1, Cx, S5	Z1, Co, S5a	Z1, Cx, S4b	Z1, Co, S5b
	60 Year										
	A1-A3	3.88E+05	5.68E+05	9.75E+05	1.95E+06	1.69E+06	1.66E+06	3.78E+06	2.38E+06	1.22E+06	3.61E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	4.91E+06	3.03E+06	2.94E+06	2.89E+06	9.13E+05	3.35E+06	1.07E+07
	B2, B4	3.97E+07	5.37E+07	2.31E+07	1.32E+08	1.29E+08	1.13E+08	3.42E+08	1.95E+08	8.85E+07	1.80E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.98E+05	7.20E+05	4.66E+05	2.74E+06	2.00E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.34E+07**	**5.75E+07**	**2.78E+07**	**1.39E+08**	**1.33E+08**	**1.20E+08**	**3.55E+08**	**2.02E+08**	**9.41E+07**	**1.98E+08**
	Total incl. D	**4.34E+07**	**5.75E+07**	**2.78E+07**	**1.39E+08**	**1.33E+08**	**1.20E+08**	**3.55E+08**	**2.02E+08**	**9.41E+07**	**1.98E+08**
	Lifecycle Module Stage	Z1, Co, S3a / m² GFA / year	Z1, Cx, S3 / m² GFA / year	Z1, Co, S3b / m² GFA / year	Z1, Co, S4a / m² GFA / year	Z1, Co, S4b / m² GFA / year	Z1, Cx, S4a / m² GFA / year	Z1, Cx, S5 / m² GFA / year	Z1, Co, S5a / m² GFA / year	Z1, Cx, S4b / m² GFA / year	Z1, Co, S5b / m² GFA / year
	A1-A3	3.20E+00	4.90E+00	8.96E+00	4.17E+00	4.77E+00	4.34E+00	2.75E+00	3.66E+00	3.07E+00	4.54E+00
	A4-A5	2.38E+01	2.35E+01	3.42E+01	1.05E+01	8.54E+00	7.69E+00	2.10E+00	1.40E+00	8.42E+00	1.35E+01
	B2, B4	3.28E+02	4.63E+02	2.13E+02	2.83E+02	3.62E+02	2.95E+02	2.49E+02	2.99E+02	2.23E+02	2.26E+02
	B6	4.74E+00	4.83E+00	2.66E+00	3.71E+00	4.26E+00	4.86E+00	3.41E+00	4.81E+00	3.65E+00	4.55E+00
	B7	4.94E+00	6.21E+00	4.28E+00	5.86E+00	5.63E+00	4.91E+00	4.09E+00	5.00E+00	3.92E+00	6.00E+00
	C1-C4	-6.39E+00	-6.28E+00	-6.91E+00	-9.86E+00	-9.57E+00	-4.07E+00	-2.60E+00	-4.48E+00	-4.74E+00	-6.18E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**3.58E+02**	**4.96E+02**	**2.56E+02**	**2.97E+02**	**3.76E+02**	**3.13E+02**	**2.58E+02**	**3.09E+02**	**2.37E+02**	**2.49E+02**
	Total incl. D	**3.58E+02**	**4.96E+02**	**2.56E+02**	**2.97E+02**	**3.76E+02**	**3.13E+02**	**2.58E+02**	**3.09E+02**	**2.37E+02**	**2.49E+02**
	Lifecycle Module Stage	Z1, Co, S3a / m² NLA / year	Z1, Cx, S3 / m² NLA / year	Z1, Co, S3b / m² NLA / year	Z1, Co, S4a / m² NLA / year	Z1, Co, S4b / m² NLA / year	Z1, Cx, S4a / m² NLA / year	Z1, Cx, S5 / m² NLA / year	Z1, Co, S5a / m² NLA / year	Z1, Cx, S4b / m² NLA / year	Z1, Co, S5b / m² NLA / year
	A1-A3	3.84E+00	5.76E+00	1.92E+01	6.39E+00	6.36E+00	5.08E+00	4.59E+00	4.33E+00	4.78E+00	5.68E+00
	A4-A5	2.86E+01	2.77E+01	7.32E+01	1.61E+01	1.14E+01	9.00E+00	3.51E+00	1.66E+00	1.31E+01	1.69E+01
	B2, B4	3.93E+02	5.45E+02	4.55E+02	4.33E+02	4.83E+02	3.45E+02	4.15E+02	3.54E+02	3.46E+02	2.83E+02
	B6	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00
	B7	5.92E+00	7.31E+00	9.16E+00	8.97E+00	7.52E+00	5.75E+00	6.83E+00	5.91E+00	6.10E+00	7.51E+00
	C1-C4	-7.67E+00	-7.39E+00	-1.48E+01	-1.51E+01	-1.28E+01	-4.76E+00	-4.33E+00	-5.30E+00	-7.38E+00	-7.73E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.30E+02**	**5.84E+02**	**5.47E+02**	**4.55E+02**	**5.02E+02**	**3.66E+02**	**4.31E+02**	**3.66E+02**	**3.69E+02**	**3.11E+02**
	Total incl. D	**4.30E+02**	**5.84E+02**	**5.47E+02**	**4.55E+02**	**5.02E+02**	**3.66E+02**	**4.31E+02**	**3.66E+02**	**3.69E+02**	**3.11E+02**

Wellington

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads

Climate Change (100 Year) Impact Potential (kg CO2 eq.)

Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
					60 Year					
A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
A4-A5	26,251	35,989	77,606	137,109	113,002	81,945	309,219	192,110	89,401	288,046
B2, B4	230,449	208,448	296,945	408,794	257,629	227,009	231,898	80,012	279,324	861,915
B6	2,383,055	2,600,044	1,180,292	6,563,163	6,219,891	5,729,375	16,434,307	8,489,184	6,776,949	10,094,000
B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
C1-C4	42,229	57,336	35,933	172,766	142,100	145,193	312,731	185,085	97,008	280,688
D	- 53,128	- 58,939	- 51,317	- 415,334	- 346,525	- 160,430	- 406,399	- 301,427	- 221,596	- 534,519
Total excl. D	**3,158,968**	**3,274,997**	**2,009,483**	**10,081,130**	**9,070,154**	**7,094,625**	**22,976,701**	**12,301,576**	**8,855,491**	**16,579,753**
Total incl. D	**3,105,840**	**3,216,059**	**1,958,166**	**9,665,796**	**8,723,629**	**6,934,194**	**22,570,301**	**12,000,149**	**8,633,896**	**16,045,234**
Lifecycle Module Stage	**Z2, Co, S3a / m² GFA / year**	**Z2, Cx, S3 / m² GFA / year**	**Z2, Co, S3b / m² GFA / year**	**Z2, Co, S4a / m² GFA / year**	**Z2, Co, S4b / m² GFA / year**	**Z2, Cx, S4a / m² GFA / year**	**Z2, Cx, S5 / m² GFA / year**	**Z2, Co, S5a / m² GFA / year**	**Z2, Cx, S4b / m² GFA / year**	**Z2, Co, S5b / m² GFA / year**
A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
A4-A5	0.22	0.31	0.71	0.29	0.32	0.21	0.22	0.29	0.22	0.36
B2, B4	1.90	1.80	2.73	0.87	0.73	0.59	0.17	0.12	0.70	1.08
B6	19.65	22.42	10.84	14.04	17.54	14.98	11.95	13.02	17.05	12.70
B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
C1-C4	0.35	0.49	0.33	0.37	0.40	0.38	0.23	0.28	0.24	0.35
D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.42	-0.30	-0.46	-0.56	-0.67
Total excl. D	**26.05**	**28.24**	**18.46**	**21.57**	**25.57**	**18.55**	**16.71**	**18.87**	**22.28**	**20.86**
Total incl. D	**25.61**	**27.73**	**17.99**	**20.68**	**24.60**	**18.13**	**16.42**	**18.41**	**21.72**	**20.19**
Lifecycle Module Stage	**Z2, Co, S3a / m² NLA / year**	**Z2, Cx, S3 / m² NLA / year**	**Z2, Co, S3b / m² NLA / year**	**Z2, Co, S4a / m² NLA / year**	**Z2, Co, S4b / m² NLA / year**	**Z2, Cx, S4a / m² NLA / year**	**Z2, Cx, S5 / m² NLA / year**	**Z2, Co, S5a / m² NLA / year**	**Z2, Cx, S4b / m² NLA / year**	**Z2, Co, S5b / m² NLA / year**
A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
A4-A5	0.26	0.37	1.53	0.45	0.43	0.25	0.38	0.35	0.35	0.45
B2, B4	2.28	2.12	5.84	1.34	0.97	0.69	0.28	0.15	1.09	1.36
B6	23.59	26.39	23.20	21.50	23.40	17.53	19.95	15.41	26.54	15.88
B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
C1-C4	0.42	0.58	0.71	0.57	0.53	0.44	0.38	0.34	0.38	0.44
D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.49	-0.49	-0.55	-0.87	-0.84
Total excl. D	**31.26**	**33.24**	**39.49**	**33.02**	**34.12**	**21.71**	**27.89**	**22.33**	**34.68**	**26.09**
Total incl. D	**30.74**	**32.64**	**38.49**	**31.66**	**32.82**	**21.22**	**27.40**	**21.79**	**33.81**	**25.25**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A1-A3	3.02E-03	5.01E-03	1.12E-02	2.03E-02	1.76E-02	1.15E-02	4.91E-02	3.06E-02	1.22E-02	4.54E-02
	A4-A5	1.02E-02	8.72E-03	1.31E-02	2.21E-02	1.50E-02	7.86E-03	1.07E-02	5.25E-03	1.59E-02	3.96E-02
	B2, B4	3.03E-02	3.67E-02	1.62E-02	8.99E-02	8.78E-02	7.76E-02	2.23E-01	1.31E-01	7.39E-02	1.20E-01
	B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
	B7	6.52E-03	6.69E-03	5.52E-03	3.01E-02	2.25E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
	C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.22E-02**	**5.77E-02**	**4.69E-02**	**1.68E-01**	**1.46E-01**	**1.19E-01**	**3.65E-01**	**2.16E-01**	**1.23E-01**	**2.70E-01**
	Total incl. D	**5.22E-02**	**5.77E-02**	**4.69E-02**	**1.68E-01**	**1.46E-01**	**1.19E-01**	**3.65E-01**	**2.16E-01**	**1.23E-01**	**2.70E-01**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	2.49E-08	4.32E-08	1.03E-07	4.35E-08	4.98E-08	3.01E-08	3.57E-08	4.69E-08	3.08E-08	5.72E-08
	A4-A5	8.43E-08	7.52E-08	1.21E-07	4.72E-08	4.22E-08	2.06E-08	7.77E-09	8.05E-09	3.99E-08	4.99E-08
	B2, B4	2.50E-07	3.17E-07	1.49E-07	1.92E-07	2.48E-07	2.03E-07	1.62E-07	2.00E-07	1.86E-07	1.51E-07
	B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
	B7	5.38E-08	5.77E-08	5.07E-08	6.45E-08	6.34E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
	C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.31E-07**	**4.97E-07**	**4.31E-07**	**3.59E-07**	**4.13E-07**	**3.12E-07**	**2.65E-07**	**3.31E-07**	**3.08E-07**	**3.40E-07**
	Total incl. D	**4.31E-07**	**4.97E-07**	**4.31E-07**	**3.59E-07**	**4.13E-07**	**3.12E-07**	**2.65E-07**	**3.31E-07**	**3.08E-07**	**3.40E-07**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	2.99E-08	5.09E-08	2.20E-07	6.67E-08	6.64E-08	3.52E-08	5.96E-08	5.56E-08	4.79E-08	7.15E-08
	A4-A5	1.01E-07	8.86E-08	2.58E-07	7.23E-08	5.64E-08	2.41E-08	1.30E-08	9.53E-09	6.22E-08	6.24E-08
	B2, B4	3.00E-07	3.73E-07	3.19E-07	2.95E-07	3.30E-07	2.38E-07	2.71E-07	2.37E-07	2.89E-07	1.89E-07
	B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
	B7	6.46E-08	6.80E-08	1.09E-07	9.87E-08	8.46E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
	C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.17E-07**	**5.85E-07**	**9.21E-07**	**5.50E-07**	**5.50E-07**	**3.65E-07**	**4.43E-07**	**3.91E-07**	**4.80E-07**	**4.25E-07**
	Total incl. D	**5.17E-07**	**5.85E-07**	**9.21E-07**	**5.50E-07**	**5.50E-07**	**3.65E-07**	**4.43E-07**	**3.91E-07**	**4.80E-07**	**4.25E-07**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Acidification Impact Potential (kg SO2 eq.) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A1-A3	2.71E+02	4.48E+02	1.05E+03	1.02E+03	1.03E+03	8.20E+02	1.98E+03	1.31E+03	7.52E+02	2.02E+03
	A4-A5	4.58E-02	6.09E+01	3.83E-02	8.29E+01	8.79E+01	7.20E+00	1.50E-01	3.37E+01	1.19E+02	1.62E-01
	B2, B4	9.04E+03	1.10E+04	4.85E+03	2.69E+04	2.63E+04	2.32E+04	6.67E+04	3.92E+04	2.20E+04	3.58E+04
	B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
	B7	7.55E+02	1.10E+03	9.86E+02	1.62E+03	1.82E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
	C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.03E+04**	**1.26E+04**	**6.90E+03**	**2.95E+04**	**2.91E+04**	**2.61E+04**	**7.28E+04**	**4.31E+04**	**2.42E+04**	**4.12E+04**
	Total incl. D	**1.03E+04**	**1.26E+04**	**6.90E+03**	**2.95E+04**	**2.91E+04**	**2.61E+04**	**7.28E+04**	**4.31E+04**	**2.42E+04**	**4.12E+04**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	2.23E-03	3.86E-03	9.60E-03	2.19E-03	2.90E-03	2.14E-03	1.44E-03	2.01E-03	1.89E-03	2.55E-03
	A4-A5	3.77E-07	5.25E-04	3.52E-07	1.77E-04	2.48E-04	1.88E-05	1.09E-07	5.17E-05	3.00E-04	2.04E-07
	B2, B4	7.46E-02	9.48E-02	4.46E-02	5.76E-02	7.41E-02	6.07E-02	4.85E-02	6.01E-02	5.53E-02	4.50E-02
	B6	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
	B7	6.23E-03	9.46E-03	9.06E-03	3.46E-03	5.12E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
	C1-C4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**8.47E-02**	**1.08E-01**	**6.34E-02**	**6.30E-02**	**8.20E-02**	**6.83E-02**	**5.29E-02**	**6.61E-02**	**6.08E-02**	**5.18E-02**
	Total incl. D	**8.47E-02**	**1.08E-01**	**6.34E-02**	**6.30E-02**	**8.20E-02**	**6.83E-02**	**5.29E-02**	**6.61E-02**	**6.08E-02**	**5.18E-02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	2.68E-03	4.55E-03	2.05E-02	3.34E-03	3.87E-03	2.51E-03	2.40E-03	2.38E-03	2.95E-03	3.19E-03
	A4-A5	4.53E-07	6.18E-04	7.53E-07	2.72E-04	3.31E-04	2.20E-05	1.82E-07	6.12E-05	4.68E-04	2.55E-07
	B2, B4	8.95E-02	1.12E-01	9.53E-02	8.81E-02	9.89E-02	7.10E-02	8.10E-02	7.11E-02	8.61E-02	5.63E-02
	B6	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
	B7	7.47E-03	1.11E-02	1.94E-02	5.30E-03	6.84E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
	C1-C4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.02E-01**	**1.28E-01**	**1.36E-01**	**9.65E-02**	**1.09E-01**	**7.99E-02**	**8.83E-02**	**7.82E-02**	**9.46E-02**	**6.48E-02**
	Total incl. D	**1.02E-01**	**1.28E-01**	**1.36E-01**	**9.65E-02**	**1.09E-01**	**7.99E-02**	**8.83E-02**	**7.82E-02**	**9.46E-02**	**6.48E-02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Eutrophication Impact Potential (kg PO4 $^{3-}$ eq.) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
		60 Year									
	A1-A3	6.05E+01	6.49E+01	1.48E+02	2.34E+02	2.03E+02	1.80E+02	4.87E+02	3.18E+02	1.65E+02	4.87E+02
	A4-A5	4.71E+02	3.55E+02	5.95E+02	8.44E+02	4.05E+02	6.77E-01	5.55E+02	1.87E+02	4.34E+02	2.05E+03
	B2, B4	4.28E+03	5.21E+03	2.30E+03	1.27E+04	1.25E+04	1.10E+04	3.16E+04	1.86E+04	1.04E+04	1.69E+04
	B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
	B7	1.84E+02	2.38E+02	2.40E+02	9.39E+02	7.23E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
	C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.08E+03**	**6.90E+03**	**3.79E+03**	**1.81E+04**	**1.66E+04**	**1.53E+04**	**4.24E+04**	**2.58E+04**	**1.45E+04**	**2.74E+04**
	Total incl. D	**6.08E+03**	**6.90E+03**	**3.79E+03**	**1.81E+04**	**1.66E+04**	**1.53E+04**	**4.24E+04**	**2.58E+04**	**1.45E+04**	**2.74E+04**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	4.99E-04	5.60E-04	1.36E-03	5.01E-04	5.72E-04	4.71E-04	3.54E-04	4.88E-04	4.15E-04	6.12E-04
	A4-A5	3.88E-03	3.06E-03	5.47E-03	1.81E-03	1.14E-03	1.77E-06	4.04E-04	2.87E-04	1.09E-03	2.58E-03
	B2, B4	3.53E-02	4.49E-02	2.11E-02	2.73E-02	3.51E-02	2.87E-02	2.30E-02	2.85E-02	2.61E-02	2.13E-02
	B6	9.46E-03	9.65E-03	5.31E-03	7.42E-03	8.51E-03	9.71E-03	6.81E-03	9.60E-03	7.30E-03	9.08E-03
	B7	1.52E-03	2.05E-03	2.20E-03	2.01E-03	2.04E-03	1.60E-03	5.82E-04	9.60E-04	2.12E-03	1.36E-03
	C1-C4	-5.15E-04	-7.41E-04	-5.85E-04	-3.67E-04	-4.80E-04	-4.08E-04	-2.57E-04	-3.41E-04	-4.49E-04	-4.67E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.01E-02**	**5.95E-02**	**3.49E-02**	**3.86E-02**	**4.69E-02**	**4.01E-02**	**3.09E-02**	**3.95E-02**	**3.65E-02**	**3.44E-02**
	Total incl. D	**5.01E-02**	**5.95E-02**	**3.49E-02**	**3.86E-02**	**4.69E-02**	**4.01E-02**	**3.09E-02**	**3.95E-02**	**3.65E-02**	**3.44E-02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	5.99E-04	6.59E-04	2.90E-03	7.67E-04	7.64E-04	5.51E-04	5.91E-04	5.77E-04	6.46E-04	7.66E-04
	A4-A5	4.66E-03	3.60E-03	1.17E-02	2.76E-03	1.52E-03	2.07E-06	6.74E-04	3.40E-04	1.70E-03	3.22E-03
	B2, B4	4.23E-02	5.29E-02	4.51E-02	4.17E-02	4.69E-02	3.36E-02	3.83E-02	3.38E-02	4.06E-02	2.66E-02
	B6	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
	B7	1.82E-03	2.41E-03	4.71E-03	3.08E-03	2.72E-03	1.87E-03	9.70E-04	1.14E-03	3.30E-03	1.70E-03
	C1-C4	-6.18E-04	-8.72E-04	-1.25E-03	-5.62E-04	-6.41E-04	-4.78E-04	-4.30E-04	-4.03E-04	-6.99E-04	-5.84E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.01E-02**	**7.00E-02**	**7.46E-02**	**5.92E-02**	**6.26E-02**	**4.69E-02**	**5.15E-02**	**4.68E-02**	**5.69E-02**	**4.31E-02**
	Total incl. D	**6.01E-02**	**7.00E-02**	**7.46E-02**	**5.92E-02**	**6.26E-02**	**4.69E-02**	**5.15E-02**	**4.68E-02**	**5.69E-02**	**4.31E-02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Tropospheric Ozone Formation Impact Potential (kg C_2H_2 eq.) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A1-A3	2.21E+01	4.69E+01	8.03E+01	1.14E+02	1.01E+02	9.92E+01	2.57E+02	1.61E+02	7.03E+01	2.52E+02
	A4-A5	6.33E+01	9.50E+01	9.07E+01	1.12E+02	1.72E+02	4.21E+02	1.50E-01	6.16E+00	1.82E+02	1.29E+01
	B2, B4	5.70E+02	6.84E+02	3.03E+02	1.68E+03	1.64E+03	1.45E+03	4.17E+03	2.41E+03	1.42E+03	2.28E+03
	B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
	B7	4.91E+01	4.10E+02	5.47E+01	1.71E+02	1.46E+02	8.05E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
	C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.88E+02**	**1.22E+03**	**4.98E+02**	**1.93E+03**	**1.95E+03**	**2.78E+03**	**4.79E+03**	**2.78E+03**	**1.74E+03**	**2.77E+03**
	Total incl. D	**6.88E+02**	**1.22E+03**	**4.98E+02**	**1.93E+03**	**1.95E+03**	**2.78E+03**	**4.79E+03**	**2.78E+03**	**1.74E+03**	**2.77E+03**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	1.82E-04	4.05E-04	7.38E-04	2.44E-04	2.84E-04	2.60E-04	1.87E-04	2.47E-04	1.77E-04	3.18E-04
	A4-A5	5.22E-04	8.19E-04	8.33E-04	2.40E-04	4.86E-04	1.10E-03	1.09E-07	9.45E-06	4.58E-04	1.63E-05
	B2, B4	4.70E-03	5.90E-03	2.78E-03	3.60E-03	4.61E-03	3.80E-03	3.03E-03	3.70E-03	3.56E-03	2.86E-03
	B6	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
	B7	4.05E-04	3.54E-03	5.03E-04	3.65E-04	4.10E-04	2.10E-03	2.46E-04	3.11E-04	2.69E-04	3.99E-04
	C1-C4	-3.74E-04	-3.77E-04	-4.15E-04	-5.04E-04	-5.01E-04	-2.24E-04	-1.51E-04	-2.49E-04	-2.79E-04	-3.43E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.68E-03**	**1.05E-02**	**4.57E-03**	**4.13E-03**	**5.51E-03**	**7.28E-03**	**3.49E-03**	**4.26E-03**	**4.37E-03**	**3.48E-03**
	Total incl. D	**5.68E-03**	**1.05E-02**	**4.57E-03**	**4.13E-03**	**5.51E-03**	**7.28E-03**	**3.49E-03**	**4.26E-03**	**4.37E-03**	**3.48E-03**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	2.19E-04	4.76E-04	1.58E-03	3.73E-04	3.79E-04	3.04E-04	3.12E-04	2.92E-04	2.75E-04	3.97E-04
	A4-A5	6.27E-04	9.65E-04	1.78E-03	3.67E-04	6.48E-04	1.29E-03	1.82E-07	1.12E-05	7.12E-04	2.04E-05
	B2, B4	5.64E-03	6.94E-03	5.95E-03	5.50E-03	6.16E-03	4.44E-03	5.06E-03	4.38E-03	5.55E-03	3.58E-03
	B6	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
	B7	4.86E-04	4.16E-03	1.08E-03	5.59E-04	5.48E-04	2.46E-03	4.10E-04	3.68E-04	4.19E-04	4.99E-04
	C1-C4	-4.49E-04	-4.44E-04	-8.88E-04	-7.72E-04	-6.68E-04	-2.62E-04	-2.52E-04	-2.95E-04	-4.34E-04	-4.29E-04
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**6.81E-03**	**1.24E-02**	**9.78E-03**	**6.32E-03**	**7.35E-03**	**8.52E-03**	**5.82E-03**	**5.04E-03**	**6.81E-03**	**4.35E-03**
	Total incl. D	**6.81E-03**	**1.24E-02**	**9.78E-03**	**6.32E-03**	**7.35E-03**	**8.52E-03**	**5.82E-03**	**5.04E-03**	**6.81E-03**	**4.35E-03**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
					60 Year					
A1-A3	2.73E+00	6.52E-02	2.94E+00	2.06E-01	2.10E-01	1.72E-01	4.20E-01	4.58E-01	1.28E+00	3.97E-01
A4-A5	4.67E-02	5.89E-02	3.95E-02	1.56E-01	1.63E-01	1.19E-01	1.51E-01	2.83E-02	1.65E-01	1.66E-01
B2, B4	4.96E+00	5.96E+00	2.64E+00	1.46E+01	1.43E+01	1.26E+01	3.63E+01	2.11E+01	1.23E+01	1.98E+01
B6	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
B7	3.71E-02	5.26E-02	2.53E-02	2.10E-01	2.02E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
C1-C4	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.42E+02**	**-1.15E+02**	**-1.65E+02**	**-2.48E+02**	**-1.62E+02**	**-3.87E+02**	**-9.63E+02**	**-6.05E+02**	**-2.68E+02**	**-8.97E+02**
Total incl. D	**-1.42E+02**	**-1.15E+02**	**-1.65E+02**	**-2.48E+02**	**-1.62E+02**	**-3.87E+02**	**-9.63E+02**	**-6.05E+02**	**-2.68E+02**	**-8.97E+02**

Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
A1-A3	2.25E-05	5.62E-07	2.70E-05	4.41E-07	5.93E-07	4.50E-07	3.06E-07	7.02E-07	3.21E-06	5.00E-07
A4-A5	3.85E-07	5.08E-07	3.63E-07	3.33E-07	4.59E-07	3.11E-07	1.10E-07	4.34E-08	4.15E-07	2.08E-07
B2, B4	4.09E-05	5.14E-05	2.42E-05	3.13E-05	4.02E-05	3.31E-05	2.64E-05	3.23E-05	3.09E-05	2.49E-05
B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.70E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.17E-03**	**-9.94E-04**	**-1.52E-03**	**-5.31E-04**	**-4.58E-04**	**-1.01E-03**	**-7.00E-04**	**-9.28E-04**	**-6.74E-04**	**-1.13E-03**
Total incl. D	**-1.17E-03**	**-9.94E-04**	**-1.52E-03**	**-5.31E-04**	**-4.58E-04**	**-1.01E-03**	**-7.00E-04**	**-9.28E-04**	**-6.74E-04**	**-1.13E-03**

Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
A1-A3	2.70E-05	6.62E-07	5.78E-05	6.75E-07	7.91E-07	5.26E-07	5.10E-07	8.31E-07	4.99E-06	6.25E-07
A4-A5	4.62E-07	5.98E-07	7.76E-07	5.10E-07	6.12E-07	3.64E-07	1.83E-07	5.14E-08	6.46E-07	2.61E-07
B2, B4	4.91E-05	6.05E-05	5.18E-05	4.79E-05	5.36E-05	3.87E-05	4.41E-05	3.83E-05	4.81E-05	3.11E-05
B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
B7	3.67E-07	5.34E-07	4.98E-07	6.88E-07	7.60E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.40E-03**	**-1.17E-03**	**-3.24E-03**	**-8.12E-04**	**-6.10E-04**	**-1.19E-03**	**-1.17E-03**	**-1.10E-03**	**-1.05E-03**	**-1.41E-03**
Total incl. D	**-1.40E-03**	**-1.17E-03**	**-3.24E-03**	**-8.12E-04**	**-6.10E-04**	**-1.19E-03**	**-1.17E-03**	**-1.10E-03**	**-1.05E-03**	**-1.41E-03**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A4-A5	3.33E+05	5.03E+05	1.05E+06	1.96E+06	1.65E+06	1.31E+06	4.26E+06	2.70E+06	1.23E+06	4.08E+06
	B2, B4	2.58E+06	2.40E+06	3.33E+06	5.01E+06	3.38E+06	2.69E+06	2.57E+06	1.07E+06	3.66E+06	9.56E+06
	B6	1.56E+07	1.77E+07	7.95E+06	4.41E+07	4.23E+07	3.84E+07	1.10E+08	5.95E+07	4.25E+07	6.49E+07
	B7	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	C1-C4	5.77E+05	6.90E+05	4.80E+05	2.64E+06	2.00E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	D	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.89E+07**	**2.11E+07**	**1.23E+07**	**5.09E+07**	**4.76E+07**	**4.42E+07**	**1.22E+08**	**6.58E+07**	**4.83E+07**	**8.12E+07**
	Total incl. D	**1.89E+07**	**2.11E+07**	**1.23E+07**	**5.09E+07**	**4.76E+07**	**4.42E+07**	**1.22E+08**	**6.58E+07**	**4.83E+07**	**8.12E+07**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	2.74E+00	4.34E+00	9.66E+00	4.19E+00	4.66E+00	3.44E+00	3.10E+00	4.15E+00	3.09E+00	5.14E+00
	A4-A5	2.13E+01	2.07E+01	3.06E+01	1.07E+01	9.54E+00	7.04E+00	1.87E+00	1.63E+00	9.21E+00	1.20E+01
	B2, B4	1.29E+02	1.52E+02	7.30E+01	9.45E+01	1.19E+02	1.00E+02	8.01E+01	9.12E+01	1.07E+02	8.16E+01
	B6	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
	B7	4.76E+00	5.95E+00	4.41E+00	5.66E+00	5.64E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.79E+00
	C1-C4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.56E+02**	**1.82E+02**	**1.13E+02**	**1.09E+02**	**1.34E+02**	**1.16E+02**	**8.91E+01**	**1.01E+02**	**1.21E+02**	**1.02E+02**
	Total incl. D	**1.56E+02**	**1.82E+02**	**1.13E+02**	**1.09E+02**	**1.34E+02**	**1.16E+02**	**8.91E+01**	**1.01E+02**	**1.21E+02**	**1.02E+02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	3.29E+00	5.11E+00	2.07E+01	6.42E+00	6.22E+00	4.02E+00	5.17E+00	4.91E+00	4.81E+00	6.43E+00
	A4-A5	2.55E+01	2.43E+01	6.54E+01	1.64E+01	1.27E+01	8.23E+00	3.12E+00	1.93E+00	1.43E+01	1.50E+01
	B2, B4	1.55E+02	1.79E+02	1.56E+02	1.45E+02	1.59E+02	1.17E+02	1.34E+02	1.08E+02	1.66E+02	1.02E+02
	B6	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
	B7	5.71E+00	7.01E+00	9.44E+00	8.66E+00	7.52E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
	C1-C4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.87E+02**	**2.14E+02**	**2.42E+02**	**1.67E+02**	**1.79E+02**	**1.35E+02**	**1.49E+02**	**1.20E+02**	**1.89E+02**	**1.28E+02**
	Total incl. D	**1.87E+02**	**2.14E+02**	**2.42E+02**	**1.67E+02**	**1.79E+02**	**1.35E+02**	**1.49E+02**	**1.20E+02**	**1.89E+02**	**1.28E+02**

Whole Building Life Cycle Assessment Reference Building Results for Wellington Excluding B6 Plug Loads											
Total Primary Energy (MJ) Impact	Lifecycle Module Stage	Z2, Co, S3a	Z2, Cx, S3	Z2, Co, S3b	Z2, Co, S4a	Z2, Co, S4b	Z2, Cx, S4a	Z2, Cx, S5	Z2, Co, S5a	Z2, Cx, S4b	Z2, Co, S5b
	60 Year										
	A1-A3	4.08E+05	5.72E+05	1.15E+06	2.18E+06	1.91E+06	1.60E+06	4.47E+06	2.85E+06	1.34E+06	4.32E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	5.60E+06	3.76E+06	2.95E+06	2.89E+06	1.19E+06	4.09E+06	1.07E+07
	B2, B4	4.30E+07	5.12E+07	2.27E+07	1.26E+08	1.22E+08	1.09E+08	3.13E+08	1.80E+08	1.08E+08	1.73E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.99E+05	7.20E+05	4.66E+05	2.75E+06	2.08E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.67E+07**	**5.50E+07**	**2.76E+07**	**1.34E+08**	**1.28E+08**	**1.16E+08**	**3.27E+08**	**1.87E+08**	**1.15E+08**	**1.91E+08**
	Total incl. D	**4.67E+07**	**5.50E+07**	**2.76E+07**	**1.34E+08**	**1.28E+08**	**1.16E+08**	**3.27E+08**	**1.87E+08**	**1.15E+08**	**1.91E+08**
	Lifecycle Module Stage	Z2, Co, S3a / m² GFA / year	Z2, Cx, S3 / m² GFA / year	Z2, Co, S3b / m² GFA / year	Z2, Co, S4a / m² GFA / year	Z2, Co, S4b / m² GFA / year	Z2, Cx, S4a / m² GFA / year	Z2, Cx, S5 / m² GFA / year	Z2, Co, S5a / m² GFA / year	Z2, Cx, S4b / m² GFA / year	Z2, Co, S5b / m² GFA / year
	A1-A3	3.37E+00	4.93E+00	1.05E+01	4.67E+00	5.37E+00	4.17E+00	3.25E+00	4.38E+00	3.38E+00	5.43E+00
	A4-A5	2.38E+01	2.35E+01	3.42E+01	1.20E+01	1.06E+01	7.71E+00	2.10E+00	1.83E+00	1.03E+01	1.35E+01
	B2, B4	3.55E+02	4.41E+02	2.09E+02	2.70E+02	3.45E+02	2.85E+02	2.28E+02	2.75E+02	2.72E+02	2.17E+02
	B6	4.74E+00	4.83E+00	2.66E+00	3.71E+00	4.26E+00	4.86E+00	3.41E+00	4.81E+00	3.65E+00	4.55E+00
	B7	4.94E+00	6.21E+00	4.28E+00	5.88E+00	5.87E+00	4.91E+00	4.09E+00	5.00E+00	3.92E+00	6.00E+00
	C1-C4	-6.39E+00	-6.28E+00	-6.91E+00	-9.86E+00	-9.57E+00	-4.07E+00	-2.60E+00	-4.48E+00	-4.74E+00	-6.18E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**3.85E+02**	**4.74E+02**	**2.53E+02**	**2.86E+02**	**3.62E+02**	**3.03E+02**	**2.38E+02**	**2.87E+02**	**2.89E+02**	**2.41E+02**
	Total incl. D	**3.85E+02**	**4.74E+02**	**2.53E+02**	**2.86E+02**	**3.62E+02**	**3.03E+02**	**2.38E+02**	**2.87E+02**	**2.89E+02**	**2.41E+02**
	Lifecycle Module Stage	Z2, Co, S3a / m² NLA / year	Z2, Cx, S3 / m² NLA / year	Z2, Co, S3b / m² NLA / year	Z2, Co, S4a / m² NLA / year	Z2, Co, S4b / m² NLA / year	Z2, Cx, S4a / m² NLA / year	Z2, Cx, S5 / m² NLA / year	Z2, Co, S5a / m² NLA / year	Z2, Cx, S4b / m² NLA / year	Z2, Co, S5b / m² NLA / year
	A1-A3	4.04E+00	5.80E+00	2.25E+01	7.14E+00	7.17E+00	4.88E+00	5.43E+00	5.18E+00	5.26E+00	6.80E+00
	A4-A5	2.86E+01	2.77E+01	7.32E+01	1.83E+01	1.41E+01	9.02E+00	3.51E+00	2.16E+00	1.60E+01	1.69E+01
	B2, B4	4.26E+02	5.19E+02	4.46E+02	4.13E+02	4.61E+02	3.34E+02	3.80E+02	3.26E+02	4.24E+02	2.72E+02
	B6	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00
	B7	5.92E+00	7.31E+00	9.16E+00	9.00E+00	7.83E+00	5.75E+00	6.83E+00	5.91E+00	6.10E+00	7.51E+00
	C1-C4	-7.67E+00	-7.39E+00	-1.48E+01	-1.51E+01	-1.28E+01	-4.76E+00	-4.33E+00	-5.30E+00	-7.38E+00	-7.73E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.62E+02**	**5.59E+02**	**5.42E+02**	**4.38E+02**	**4.83E+02**	**3.54E+02**	**3.97E+02**	**3.40E+02**	**4.50E+02**	**3.01E+02**
	Total incl. D	**4.62E+02**	**5.59E+02**	**5.42E+02**	**4.38E+02**	**4.83E+02**	**3.54E+02**	**3.97E+02**	**3.40E+02**	**4.50E+02**	**3.01E+02**

Christchurch

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads

Climate Change (100 Year) Impact Potential (kg CO2 eq.)

Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
					60 Year					
A1-A3	415,550	313,281	387,772	2,613,688	2,175,925	712,433	5,187,639	3,020,299	1,457,551	4,668,708
A4-A5	31,485	34,067	80,034	152,420	124,488	88,316	296,226	189,682	97,478	277,253
B2, B4	230,449	208,448	296,945	408,794	257,629	227,009	231,898	80,012	279,324	861,915
B6	3,041,475	3,207,366	1,479,557	8,463,798	7,909,905	7,366,280	21,340,092	9,395,791	8,717,351	13,800,661
B7	61,432	59,900	30,935	185,610	161,606	198,670	500,907	334,886	155,259	386,396
C1-C4	42,229	57,336	35,933	172,229	136,692	145,193	312,731	185,085	97,008	280,688
D	- 53,128	- 58,939	- 51,317	- 415,334	- 346,525	- 162,533	- 406,399	- 301,427	- 221,596	- 534,519
Total excl. D	**3,822,622**	**3,880,398**	**2,311,175**	**11,996,538**	**10,766,246**	**8,737,901**	**27,869,493**	**13,205,754**	**10,803,971**	**20,275,621**
Total incl. D	**3,769,493**	**3,821,459**	**2,259,858**	**11,581,204**	**10,419,721**	**8,575,368**	**27,463,094**	**12,904,328**	**10,582,375**	**19,741,102**
Lifecycle Module Stage	**Z3, Co, S3a / m² GFA / year**	**Z3, Cx, S3 / m² GFA / year**	**Z3, Co, S3b / m² GFA / year**	**Z3, Co, S4a / m² GFA / year**	**Z3, Co, S4b / m² GFA / year**	**Z3, Cx, S4a / m² GFA / year**	**Z3, Cx, S5 / m² GFA / year**	**Z3, Co, S5a / m² GFA / year**	**Z3, Cx, S4b / m² GFA / year**	**Z3, Co, S5b / m² GFA / year**
A1-A3	3.43	2.70	3.56	5.59	6.14	1.86	3.77	4.63	3.67	5.87
A4-A5	0.26	0.29	0.74	0.33	0.35	0.23	0.22	0.29	0.25	0.35
B2, B4	1.90	1.80	2.73	0.87	0.73	0.59	0.17	0.12	0.70	1.08
B6	25.08	27.65	13.59	18.11	22.30	19.26	15.52	14.41	21.93	17.36
B7	0.51	0.52	0.28	0.40	0.46	0.52	0.36	0.51	0.39	0.49
C1-C4	0.35	0.49	0.33	0.37	0.39	0.38	0.23	0.28	0.24	0.35
D	-0.44	-0.51	-0.47	-0.89	-0.98	-0.43	-0.30	-0.46	-0.56	-0.67
Total excl. D	**31.52**	**33.46**	**21.23**	**25.67**	**30.36**	**22.85**	**20.27**	**20.26**	**27.18**	**25.51**
Total incl. D	**31.09**	**32.95**	**20.76**	**24.78**	**29.38**	**22.43**	**19.98**	**19.80**	**26.62**	**24.84**
Lifecycle Module Stage	**Z3, Co, S3a / m² NLA / year**	**Z3, Cx, S3 / m² NLA / year**	**Z3, Co, S3b / m² NLA / year**	**Z3, Co, S4a / m² NLA / year**	**Z3, Co, S4b / m² NLA / year**	**Z3, Cx, S4a / m² NLA / year**	**Z3, Cx, S5 / m² NLA / year**	**Z3, Co, S5a / m² NLA / year**	**Z3, Cx, S4b / m² NLA / year**	**Z3, Co, S5b / m² NLA / year**
A1-A3	4.11	3.18	7.62	8.56	8.19	2.18	6.30	5.48	5.71	7.35
A4-A5	0.31	0.35	1.57	0.50	0.47	0.27	0.36	0.34	0.38	0.44
B2, B4	2.28	2.12	5.84	1.34	0.97	0.69	0.28	0.15	1.09	1.36
B6	30.10	32.56	29.08	27.72	29.76	22.54	25.90	17.06	34.14	21.72
B7	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
C1-C4	0.42	0.58	0.71	0.56	0.51	0.44	0.38	0.34	0.38	0.44
D	-0.53	-0.60	-1.01	-1.36	-1.30	-0.50	-0.49	-0.55	-0.87	-0.84
Total excl. D	**37.83**	**39.39**	**45.42**	**39.30**	**40.51**	**26.74**	**33.83**	**23.98**	**42.31**	**31.90**
Total incl. D	**37.31**	**38.79**	**44.42**	**37.94**	**39.20**	**26.24**	**33.33**	**23.43**	**41.44**	**31.06**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads											
Stratospheric Ozone Depletion Impact Potential (kg CFC 11 eq.) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
		60 Year									
	A1-A3	4.01E-03	4.65E-03	1.17E-02	2.32E-02	1.98E-02	1.27E-02	4.66E-02	3.01E-02	1.38E-02	4.34E-02
	A4-A5	1.02E-02	8.72E-03	1.31E-02	2.21E-02	1.50E-02	7.86E-03	1.07E-02	5.25E-03	1.59E-02	3.96E-02
	B2, B4	3.56E-02	4.15E-02	1.82E-02	1.04E-01	9.95E-02	8.91E-02	2.54E-01	1.36E-01	9.03E-02	1.50E-01
	B6	2.86E-03	2.79E-03	1.44E-03	8.65E-03	7.53E-03	9.26E-03	2.34E-02	1.56E-02	7.24E-03	1.80E-02
	B7	6.52E-03	6.69E-03	5.52E-03	3.00E-02	2.15E-02	1.64E-02	6.57E-02	3.76E-02	1.75E-02	5.43E-02
	C1-C4	-6.73E-04	-2.28E-03	-6.24E-04	-3.39E-03	-4.16E-03	-3.22E-03	-7.14E-03	-4.18E-03	-4.22E-03	-7.56E-03
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.85E-02**	**6.21E-02**	**4.94E-02**	**1.85E-01**	**1.59E-01**	**1.32E-01**	**3.93E-01**	**2.20E-01**	**1.40E-01**	**2.98E-01**
	Total incl. D	**5.85E-02**	**6.21E-02**	**4.94E-02**	**1.85E-01**	**1.59E-01**	**1.32E-01**	**3.93E-01**	**2.20E-01**	**1.40E-01**	**2.98E-01**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	3.31E-08	4.01E-08	1.07E-07	4.97E-08	5.58E-08	3.33E-08	3.39E-08	4.62E-08	3.46E-08	5.46E-08
	A4-A5	8.43E-08	7.52E-08	1.21E-07	4.72E-08	4.22E-08	2.06E-08	7.77E-09	8.05E-09	3.99E-08	4.99E-08
	B2, B4	2.94E-07	3.58E-07	1.67E-07	2.23E-07	2.81E-07	2.33E-07	1.85E-07	2.08E-07	2.27E-07	1.88E-07
	B6	2.36E-08	2.41E-08	1.33E-08	1.85E-08	2.12E-08	2.42E-08	1.70E-08	2.40E-08	1.82E-08	2.27E-08
	B7	5.38E-08	5.77E-08	5.07E-08	6.43E-08	6.05E-08	4.28E-08	4.78E-08	5.77E-08	4.39E-08	6.83E-08
	C1-C4	-5.55E-09	-1.96E-08	-5.73E-09	-7.26E-09	-1.17E-08	-8.43E-09	-5.19E-09	-6.41E-09	-1.06E-08	-9.51E-09
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.83E-07**	**5.36E-07**	**4.53E-07**	**3.95E-07**	**4.49E-07**	**3.45E-07**	**2.86E-07**	**3.38E-07**	**3.53E-07**	**3.74E-07**
	Total incl. D	**4.83E-07**	**5.36E-07**	**4.53E-07**	**3.95E-07**	**4.49E-07**	**3.45E-07**	**2.86E-07**	**3.38E-07**	**3.53E-07**	**3.74E-07**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	3.97E-08	4.72E-08	2.30E-07	7.60E-08	7.45E-08	3.90E-08	5.66E-08	5.47E-08	5.39E-08	6.82E-08
	A4-A5	1.01E-07	8.86E-08	2.58E-07	7.23E-08	5.64E-08	2.41E-08	1.30E-08	9.53E-09	6.22E-08	6.24E-08
	B2, B4	3.52E-07	4.22E-07	3.58E-07	3.41E-07	3.74E-07	2.73E-07	3.08E-07	2.46E-07	3.54E-07	2.36E-07
	B6	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08	2.83E-08
	B7	6.46E-08	6.80E-08	1.09E-07	9.84E-08	8.08E-08	5.00E-08	7.97E-08	6.83E-08	6.84E-08	8.54E-08
	C1-C4	-6.66E-09	-2.31E-08	-1.23E-08	-1.11E-08	-1.56E-08	-9.87E-09	-8.66E-09	-7.58E-09	-1.65E-08	-1.19E-08
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.79E-07**	**6.31E-07**	**9.70E-07**	**6.05E-07**	**5.99E-07**	**4.04E-07**	**4.77E-07**	**4.00E-07**	**5.50E-07**	**4.68E-07**
	Total incl. D	**5.79E-07**	**6.31E-07**	**9.70E-07**	**6.05E-07**	**5.99E-07**	**4.04E-07**	**4.77E-07**	**4.00E-07**	**5.50E-07**	**4.68E-07**

Acidification Impact Potential (kg SO2 eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads										
Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
60 Year										
A1-A3	2.94E+02	4.40E+02	1.06E+03	1.10E+03	1.09E+03	8.47E+02	1.93E+03	1.31E+03	7.89E+02	1.99E+03
A4-A5	4.58E-02	6.09E+01	3.83E-02	8.29E+01	8.79E+01	7.20E+00	1.50E-01	3.37E+01	1.19E+02	1.62E-01
B2, B4	1.06E+04	1.24E+04	5.43E+03	3.11E+04	2.97E+04	2.66E+04	7.58E+04	4.06E+04	2.68E+04	4.45E+04
B6	3.76E+02	3.66E+02	1.89E+02	1.13E+03	9.88E+02	1.21E+03	3.06E+03	2.05E+03	9.49E+02	2.36E+03
B7	7.55E+02	1.10E+03	9.86E+02	1.61E+03	1.77E+03	1.42E+03	2.35E+03	1.48E+03	1.17E+03	2.71E+03
C1-C4	-1.76E+02	-3.81E+02	-1.66E+02	-1.31E+03	-1.13E+03	-5.75E+02	-1.34E+03	-9.67E+02	-8.11E+02	-1.72E+03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.19E+04**	**1.40E+04**	**7.50E+03**	**3.37E+04**	**3.25E+04**	**2.95E+04**	**8.18E+04**	**4.45E+04**	**2.90E+04**	**4.99E+04**
Total incl. D	**1.19E+04**	**1.40E+04**	**7.50E+03**	**3.37E+04**	**3.25E+04**	**2.95E+04**	**8.18E+04**	**4.45E+04**	**2.90E+04**	**4.99E+04**
Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
A1-A3	2.43E-03	3.80E-03	9.70E-03	2.35E-03	3.06E-03	2.22E-03	1.40E-03	2.01E-03	1.99E-03	2.51E-03
A4-A5	3.77E-07	5.25E-04	3.52E-07	1.77E-04	2.48E-04	1.88E-05	1.09E-07	5.17E-05	3.00E-04	2.04E-07
B2, B4	8.75E-02	1.07E-01	4.99E-02	6.65E-02	8.38E-02	6.95E-02	5.51E-02	6.23E-02	6.74E-02	5.60E-02
B6	3.10E-03	3.16E-03	1.74E-03	2.43E-03	2.79E-03	3.18E-03	2.23E-03	3.14E-03	2.39E-03	2.97E-03
B7	6.23E-03	9.46E-03	9.06E-03	3.45E-03	4.98E-03	3.72E-03	1.71E-03	2.27E-03	2.94E-03	3.41E-03
C1-C4	-1.45E-03	-3.29E-03	-1.52E-03	-2.80E-03	-3.18E-03	-1.50E-03	-9.71E-04	-1.48E-03	-2.04E-03	-2.17E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**9.78E-02**	**1.21E-01**	**6.89E-02**	**7.21E-02**	**9.17E-02**	**7.71E-02**	**5.95E-02**	**6.83E-02**	**7.30E-02**	**6.28E-02**
Total incl. D	**9.78E-02**	**1.21E-01**	**6.89E-02**	**7.21E-02**	**9.17E-02**	**7.71E-02**	**5.95E-02**	**6.83E-02**	**7.30E-02**	**6.28E-02**
Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
A1-A3	2.91E-03	4.47E-03	2.08E-02	3.60E-03	4.08E-03	2.59E-03	2.34E-03	2.38E-03	3.09E-03	3.14E-03
A4-A5	4.53E-07	6.18E-04	7.53E-07	2.72E-04	3.31E-04	2.20E-05	1.82E-07	6.12E-05	4.68E-04	2.55E-07
B2, B4	1.05E-01	1.26E-01	1.07E-01	1.02E-01	1.12E-01	8.13E-02	9.20E-02	7.38E-02	1.05E-01	7.01E-02
B6	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03	3.72E-03
B7	7.47E-03	1.11E-02	1.94E-02	5.29E-03	6.65E-03	4.35E-03	2.85E-03	2.69E-03	4.58E-03	4.26E-03
C1-C4	-1.74E-03	-3.87E-03	-3.26E-03	-4.29E-03	-4.24E-03	-1.76E-03	-1.62E-03	-1.76E-03	-3.17E-03	-2.71E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**1.17E-01**	**1.42E-01**	**1.47E-01**	**1.10E-01**	**1.22E-01**	**9.02E-02**	**9.92E-02**	**8.08E-02**	**1.14E-01**	**7.85E-02**
Total incl. D	**1.17E-01**	**1.42E-01**	**1.47E-01**	**1.10E-01**	**1.22E-01**	**9.02E-02**	**9.92E-02**	**8.08E-02**	**1.14E-01**	**7.85E-02**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads

Eutrophication Impact Potential (kg PO_4^{3-} eq.) Impact

Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
60 Year										
A1-A3	6.65E+01	6.27E+01	1.50E+02	2.52E+02	2.16E+02	1.87E+02	4.72E+02	3.15E+02	1.74E+02	4.75E+02
A4-A5	4.71E+02	3.55E+02	5.95E+02	8.44E+02	4.05E+02	6.77E-01	5.55E+02	1.87E+02	4.34E+02	2.05E+03
B2, B4	5.01E+03	5.87E+03	2.57E+03	1.47E+04	1.41E+04	1.26E+04	3.58E+04	1.93E+04	1.26E+04	2.10E+04
B6	1.15E+03	1.12E+03	5.78E+02	3.47E+03	3.02E+03	3.71E+03	9.36E+03	6.26E+03	2.90E+03	7.22E+03
B7	1.84E+02	2.38E+02	2.40E+02	9.38E+02	7.13E+02	6.12E+02	7.99E+02	6.26E+02	8.43E+02	1.08E+03
C1-C4	-6.24E+01	-8.59E+01	-6.36E+01	-1.71E+02	-1.70E+02	-1.56E+02	-3.54E+02	-2.22E+02	-1.78E+02	-3.71E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**6.81E+03**	**7.56E+03**	**4.07E+03**	**2.00E+04**	**1.82E+04**	**1.69E+04**	**4.66E+04**	**2.64E+04**	**1.68E+04**	**3.14E+04**
Total incl. D	**6.81E+03**	**7.56E+03**	**4.07E+03**	**2.00E+04**	**1.82E+04**	**1.69E+04**	**4.66E+04**	**2.64E+04**	**1.68E+04**	**3.14E+04**
Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
A1-A3	5.48E-04	5.41E-04	1.38E-03	5.40E-04	6.10E-04	4.90E-04	3.43E-04	4.84E-04	4.38E-04	5.97E-04
A4-A5	3.88E-03	3.06E-03	5.47E-03	1.81E-03	1.14E-03	1.77E-06	4.04E-04	2.87E-04	1.09E-03	2.58E-03
B2, B4	4.13E-02	5.06E-02	2.36E-02	3.14E-02	3.96E-02	3.28E-02	2.60E-02	2.95E-02	3.17E-02	2.64E-02
B6	9.46E-03	9.65E-03	5.31E-03	7.42E-03	8.51E-03	9.71E-03	6.81E-03	9.60E-03	7.30E-03	9.08E-03
B7	1.52E-03	2.05E-03	2.20E-03	2.01E-03	2.01E-03	1.60E-03	5.82E-04	9.60E-04	2.12E-03	1.36E-03
C1-C4	-5.15E-04	-7.41E-04	-5.85E-04	-3.67E-04	-4.80E-04	-4.08E-04	-2.57E-04	-3.41E-04	-4.49E-04	-4.67E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**5.62E-02**	**6.52E-02**	**3.74E-02**	**4.29E-02**	**5.14E-02**	**4.42E-02**	**3.39E-02**	**4.05E-02**	**4.22E-02**	**3.96E-02**
Total incl. D	**5.62E-02**	**6.52E-02**	**3.74E-02**	**4.29E-02**	**5.14E-02**	**4.42E-02**	**3.39E-02**	**4.05E-02**	**4.22E-02**	**3.96E-02**
Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
A1-A3	6.58E-04	6.36E-04	2.95E-03	8.26E-04	8.14E-04	5.73E-04	5.73E-04	5.73E-04	6.82E-04	7.47E-04
A4-A5	4.66E-03	3.60E-03	1.17E-02	2.76E-03	1.52E-03	2.07E-06	6.74E-04	3.40E-04	1.70E-03	3.22E-03
B2, B4	4.96E-02	5.96E-02	5.05E-02	4.81E-02	5.29E-02	3.84E-02	4.34E-02	3.50E-02	4.94E-02	3.30E-02
B6	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
B7	1.82E-03	2.41E-03	4.71E-03	3.07E-03	2.68E-03	1.87E-03	9.70E-04	1.14E-03	3.30E-03	1.70E-03
C1-C4	-6.18E-04	-8.72E-04	-1.25E-03	-5.62E-04	-6.41E-04	-4.78E-04	-4.30E-04	-4.03E-04	-6.99E-04	-5.84E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**6.74E-02**	**7.67E-02**	**7.99E-02**	**6.56E-02**	**6.86E-02**	**5.17E-02**	**5.66E-02**	**4.80E-02**	**6.58E-02**	**4.95E-02**
Total incl. D	**6.74E-02**	**7.67E-02**	**7.99E-02**	**6.56E-02**	**6.86E-02**	**5.17E-02**	**5.66E-02**	**4.80E-02**	**6.58E-02**	**4.95E-02**

Tropospheric Ozone Formation Impact Potential (kg C2H2 eq.) Impact

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads										
Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
60 Year										
A1-A3	3.14E+01	3.48E+01	8.54E+01	1.41E+02	1.19E+02	8.29E+01	2.70E+02	1.71E+02	8.73E+01	2.61E+02
A4-A5	6.33E+01	9.50E+01	9.07E+01	1.12E+02	1.72E+02	4.21E+02	1.50E-01	6.16E+00	1.82E+02	1.29E+01
B2, B4	6.76E+02	7.81E+02	3.44E+02	1.97E+03	1.88E+03	1.69E+03	4.82E+03	2.52E+03	1.74E+03	2.87E+03
B6	2.88E+01	2.81E+01	1.45E+01	8.70E+01	7.58E+01	9.31E+01	2.35E+02	1.57E+02	7.28E+01	1.81E+02
B7	4.91E+01	6.61E+01	5.47E+01	1.70E+02	1.39E+02	1.35E+02	3.38E+02	2.02E+02	1.07E+02	3.17E+02
C1-C4	-4.53E+01	-4.38E+01	-4.52E+01	-2.36E+02	-1.78E+02	-8.57E+01	-2.07E+02	-1.62E+02	-1.11E+02	-2.73E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**8.04E+02**	**9.61E+02**	**5.44E+02**	**2.24E+03**	**2.21E+03**	**2.33E+03**	**5.46E+03**	**2.90E+03**	**2.08E+03**	**3.37E+03**
Total incl. D	**8.04E+02**	**9.61E+02**	**5.44E+02**	**2.24E+03**	**2.21E+03**	**2.33E+03**	**5.46E+03**	**2.90E+03**	**2.08E+03**	**3.37E+03**
Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
A1-A3	2.59E-04	3.00E-04	7.85E-04	3.01E-04	3.37E-04	2.17E-04	1.97E-04	2.63E-04	2.20E-04	3.28E-04
A4-A5	5.22E-04	8.19E-04	8.33E-04	2.40E-04	4.86E-04	1.10E-03	1.09E-07	9.45E-06	4.58E-04	1.63E-05
B2, B4	5.58E-03	6.73E-03	3.16E-03	4.21E-03	5.29E-03	4.41E-03	3.51E-03	3.87E-03	4.38E-03	3.61E-03
B6	2.37E-04	2.42E-04	1.33E-04	1.86E-04	2.14E-04	2.44E-04	1.71E-04	2.41E-04	1.83E-04	2.28E-04
B7	4.05E-04	5.70E-04	5.03E-04	3.64E-04	3.93E-04	3.52E-04	2.46E-04	3.11E-04	2.69E-04	3.99E-04
C1-C4	-3.74E-04	-3.77E-04	-4.15E-04	-5.04E-04	-5.01E-04	-2.24E-04	-1.51E-04	-2.49E-04	-2.79E-04	-3.43E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**6.63E-03**	**8.28E-03**	**5.00E-03**	**4.80E-03**	**6.22E-03**	**6.10E-03**	**3.97E-03**	**4.44E-03**	**5.23E-03**	**4.24E-03**
Total incl. D	**6.63E-03**	**8.28E-03**	**5.00E-03**	**4.80E-03**	**6.22E-03**	**6.10E-03**	**3.97E-03**	**4.44E-03**	**5.23E-03**	**4.24E-03**
Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
A1-A3	3.11E-04	3.53E-04	1.68E-03	4.61E-04	4.49E-04	2.54E-04	3.28E-04	3.11E-04	3.42E-04	4.10E-04
A4-A5	6.27E-04	9.65E-04	1.78E-03	3.67E-04	6.48E-04	1.29E-03	1.82E-07	1.12E-05	7.12E-04	2.04E-05
B2, B4	6.70E-03	7.92E-03	6.76E-03	6.45E-03	7.06E-03	5.16E-03	5.85E-03	4.58E-03	6.82E-03	4.52E-03
B6	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04	2.85E-04
B7	4.86E-04	6.71E-04	1.08E-03	5.57E-04	5.24E-04	4.12E-04	4.10E-04	3.68E-04	4.19E-04	4.99E-04
C1-C4	-4.49E-04	-4.44E-04	-8.88E-04	-7.72E-04	-6.68E-04	-2.62E-04	-2.52E-04	-2.95E-04	-4.34E-04	-4.29E-04
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**7.96E-03**	**9.75E-03**	**1.07E-02**	**7.35E-03**	**8.30E-03**	**7.14E-03**	**6.62E-03**	**5.26E-03**	**8.14E-03**	**5.30E-03**
Total incl. D	**7.96E-03**	**9.75E-03**	**1.07E-02**	**7.35E-03**	**8.30E-03**	**7.14E-03**	**6.62E-03**	**5.26E-03**	**8.14E-03**	**5.30E-03**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads

Total Mineral Depletion (depletion abiotic resources (elements) Non-Fossil fuels kg Sb eq.) Impact

Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
					60 Year					
A1-A3	2.74E+00	6.07E-02	2.94E+00	2.40E-01	2.36E-01	1.87E-01	3.90E-01	4.51E-01	1.29E+00	3.72E-01
A4-A5	4.67E-02	5.89E-02	3.95E-02	1.56E-01	1.63E-01	1.19E-01	1.51E-01	2.83E-02	1.65E-01	1.66E-01
B2, B4	5.87E+00	6.79E+00	2.99E+00	1.71E+01	1.63E+01	1.47E+01	4.18E+01	2.20E+01	1.51E+01	2.49E+01
B6	2.47E-01	2.41E-01	1.24E-01	7.46E-01	6.50E-01	7.99E-01	2.01E+00	1.35E+00	6.24E-01	1.55E+00
B7	3.71E-02	5.26E-02	2.53E-02	2.10E-01	1.99E-01	1.40E-01	4.38E-01	2.47E-01	1.64E-01	4.01E-01
C1-C4	-1.50E+02	-1.22E+02	-1.71E+02	-2.64E+02	-1.78E+02	-4.01E+02	-1.00E+03	-6.28E+02	-2.83E+02	-9.20E+02
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.41E+02**	**-1.14E+02**	**-1.65E+02**	**-2.45E+02**	**-1.60E+02**	**-3.85E+02**	**-9.57E+02**	**-6.04E+02**	**-2.65E+02**	**-8.92E+02**
Total incl. D	**-1.41E+02**	**-1.14E+02**	**-1.65E+02**	**-2.45E+02**	**-1.60E+02**	**-3.85E+02**	**-9.57E+02**	**-6.04E+02**	**-2.65E+02**	**-8.92E+02**
Lifecycle Module Stage	**Z3, Co, S3a / m² GFA / year**	**Z3, Cx, S3 / m² GFA / year**	**Z3, Co, S3b / m² GFA / year**	**Z3, Co, S4a / m² GFA / year**	**Z3, Co, S4b / m² GFA / year**	**Z3, Cx, S4a / m² GFA / year**	**Z3, Cx, S5 / m² GFA / year**	**Z3, Co, S5a / m² GFA / year**	**Z3, Cx, S4b / m² GFA / year**	**Z3, Co, S5b / m² GFA / year**
A1-A3	2.26E-05	5.24E-07	2.70E-05	5.13E-07	6.65E-07	4.88E-07	2.84E-07	6.93E-07	3.25E-06	4.68E-07
A4-A5	3.85E-07	5.08E-07	3.63E-07	3.33E-07	4.59E-07	3.11E-07	1.10E-07	4.34E-08	4.15E-07	2.08E-07
B2, B4	4.84E-05	5.86E-05	2.75E-05	3.66E-05	4.60E-05	3.83E-05	3.04E-05	3.37E-05	3.79E-05	3.13E-05
B6	2.04E-06	2.08E-06	1.14E-06	1.60E-06	1.83E-06	2.09E-06	1.47E-06	2.07E-06	1.57E-06	1.95E-06
B7	3.06E-07	4.53E-07	2.33E-07	4.49E-07	5.62E-07	3.65E-07	3.18E-07	3.79E-07	4.12E-07	5.04E-07
C1-C4	-1.24E-03	-1.05E-03	-1.57E-03	-5.65E-04	-5.01E-04	-1.05E-03	-7.29E-04	-9.64E-04	-7.11E-04	-1.16E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.16E-03**	**-9.87E-04**	**-1.51E-03**	**-5.25E-04**	**-4.52E-04**	**-1.01E-03**	**-6.96E-04**	**-9.27E-04**	**-6.67E-04**	**-1.12E-03**
Total incl. D	**-1.16E-03**	**-9.87E-04**	**-1.51E-03**	**-5.25E-04**	**-4.52E-04**	**-1.01E-03**	**-6.96E-04**	**-9.27E-04**	**-6.67E-04**	**-1.12E-03**
Lifecycle Module Stage	**Z3, Co, S3a / m² NLA / year**	**Z3, Cx, S3 / m² NLA / year**	**Z3, Co, S3b / m² NLA / year**	**Z3, Co, S4a / m² NLA / year**	**Z3, Co, S4b / m² NLA / year**	**Z3, Cx, S4a / m² NLA / year**	**Z3, Cx, S5 / m² NLA / year**	**Z3, Co, S5a / m² NLA / year**	**Z3, Cx, S4b / m² NLA / year**	**Z3, Co, S5b / m² NLA / year**
A1-A3	2.72E-05	6.17E-07	5.79E-05	7.85E-07	8.87E-07	5.71E-07	4.74E-07	8.20E-07	5.06E-06	5.85E-07
A4-A5	4.62E-07	5.98E-07	7.76E-07	5.10E-07	6.12E-07	3.64E-07	1.83E-07	5.14E-08	6.46E-07	2.61E-07
B2, B4	5.81E-05	6.89E-05	5.87E-05	5.60E-05	6.14E-05	4.48E-05	5.08E-05	3.99E-05	5.90E-05	3.92E-05
B6	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
B7	3.67E-07	5.34E-07	4.98E-07	6.87E-07	7.50E-07	4.27E-07	5.31E-07	4.49E-07	6.41E-07	6.31E-07
C1-C4	-1.48E-03	-1.23E-03	-3.36E-03	-8.64E-04	-6.69E-04	-1.23E-03	-1.22E-03	-1.14E-03	-1.11E-03	-1.45E-03
D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total excl. D	**-1.39E-03**	**-1.16E-03**	**-3.24E-03**	**-8.04E-04**	**-6.03E-04**	**-1.18E-03**	**-1.16E-03**	**-1.10E-03**	**-1.04E-03**	**-1.40E-03**
Total incl. D	**-1.39E-03**	**-1.16E-03**	**-3.24E-03**	**-8.04E-04**	**-6.03E-04**	**-1.18E-03**	**-1.16E-03**	**-1.10E-03**	**-1.04E-03**	**-1.40E-03**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads											
Total Fossil Fuel Depletion (depletion of abiotic resources (fossil fuels) MJ(NCV)) Impact	Lifecycle Module Stage	Z3, Co, S3a	Z3, Cx, S3	Z3, Co, S3b	Z3, Co, S4a	Z3, Co, S4b	Z3, Cx, S4a	Z3, Cx, S5	Z3, Co, S5a	Z3, Cx, S4b	Z3, Co, S5b
		60 Year									
	A4-A5	4.14E+05	4.73E+05	1.09E+06	2.20E+06	1.83E+06	1.42E+06	4.06E+06	2.67E+06	1.35E+06	3.92E+06
	B2, B4	2.58E+06	2.40E+06	3.33E+06	5.01E+06	3.38E+06	2.69E+06	2.57E+06	1.07E+06	3.66E+06	9.56E+06
	B6	1.95E+07	2.12E+07	9.61E+06	5.50E+07	5.17E+07	4.76E+07	1.37E+08	6.43E+07	5.38E+07	8.63E+07
	B7	3.88E+05	3.78E+05	1.95E+05	1.17E+06	1.02E+06	1.25E+06	3.16E+06	2.11E+06	9.80E+05	2.44E+06
	C1-C4	5.77E+05	6.90E+05	4.80E+05	2.64E+06	1.92E+06	1.80E+06	5.44E+06	3.14E+06	1.50E+06	4.60E+06
	D	-6.32E+05	-5.24E+05	-6.87E+05	-4.01E+06	-2.71E+06	-1.23E+06	-3.16E+06	-2.64E+06	-1.54E+06	-4.34E+06
	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.28E+07**	**2.46E+07**	**1.40E+07**	**6.20E+07**	**5.72E+07**	**5.35E+07**	**1.49E+08**	**7.07E+07**	**5.98E+07**	**1.03E+08**
	Total incl. D	**2.28E+07**	**2.46E+07**	**1.40E+07**	**6.20E+07**	**5.72E+07**	**5.35E+07**	**1.49E+08**	**7.07E+07**	**5.98E+07**	**1.03E+08**
	Lifecycle Module Stage	Z3, Co, S3a / m² GFA / year	Z3, Cx, S3 / m² GFA / year	Z3, Co, S3b / m² GFA / year	Z3, Co, S4a / m² GFA / year	Z3, Co, S4b / m² GFA / year	Z3, Cx, S4a / m² GFA / year	Z3, Cx, S5 / m² GFA / year	Z3, Co, S5a / m² GFA / year	Z3, Cx, S4b / m² GFA / year	Z3, Co, S5b / m² GFA / year
	A1-A3	3.42E+00	4.08E+00	1.00E+01	4.70E+00	5.17E+00	3.70E+00	2.95E+00	4.09E+00	3.41E+00	4.93E+00
	A4-A5	2.13E+01	2.07E+01	3.06E+01	1.07E+01	9.54E+00	7.04E+00	1.87E+00	1.63E+00	9.21E+00	1.20E+01
	B2, B4	1.60E+02	1.83E+02	8.83E+01	1.18E+02	1.46E+02	1.24E+02	9.98E+01	9.87E+01	1.35E+02	1.09E+02
	B6	3.20E+00	3.26E+00	1.79E+00	2.51E+00	2.88E+00	3.28E+00	2.30E+00	3.24E+00	2.47E+00	3.07E+00
	B7	4.76E+00	5.95E+00	4.41E+00	5.64E+00	5.41E+00	4.70E+00	3.95E+00	4.82E+00	3.77E+00	5.79E+00
	C1-C4	-5.21E+00	-4.52E+00	-6.32E+00	-8.58E+00	-7.65E+00	-3.22E+00	-2.30E+00	-4.05E+00	-3.89E+00	-5.46E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**1.88E+02**	**2.12E+02**	**1.29E+02**	**1.33E+02**	**1.61E+02**	**1.40E+02**	**1.09E+02**	**1.08E+02**	**1.50E+02**	**1.29E+02**
	Total incl. D	**1.88E+02**	**2.12E+02**	**1.29E+02**	**1.33E+02**	**1.61E+02**	**1.40E+02**	**1.09E+02**	**1.08E+02**	**1.50E+02**	**1.29E+02**
	Lifecycle Module Stage	Z3, Co, S3a / m² NLA / year	Z3, Cx, S3 / m² NLA / year	Z3, Co, S3b / m² NLA / year	Z3, Co, S4a / m² NLA / year	Z3, Co, S4b / m² NLA / year	Z3, Cx, S4a / m² NLA / year	Z3, Cx, S5 / m² NLA / year	Z3, Co, S5a / m² NLA / year	Z3, Cx, S4b / m² NLA / year	Z3, Co, S5b / m² NLA / year
	A1-A3	4.10E+00	4.80E+00	2.14E+01	7.20E+00	6.89E+00	4.33E+00	4.93E+00	4.84E+00	5.30E+00	6.17E+00
	A4-A5	2.55E+01	2.43E+01	6.54E+01	1.64E+01	1.27E+01	8.23E+00	3.12E+00	1.93E+00	1.43E+01	1.50E+01
	B2, B4	1.93E+02	2.15E+02	1.89E+02	1.80E+02	1.95E+02	1.46E+02	1.67E+02	1.17E+02	2.11E+02	1.36E+02
	B6	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00	3.84E+00
	B7	5.71E+00	7.01E+00	9.44E+00	8.63E+00	7.22E+00	5.50E+00	6.60E+00	5.71E+00	5.87E+00	7.24E+00
	C1-C4	-6.26E+00	-5.32E+00	-1.35E+01	-1.31E+01	-1.02E+01	-3.77E+00	-3.84E+00	-4.79E+00	-6.05E+00	-6.83E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**2.25E+02**	**2.50E+02**	**2.75E+02**	**2.03E+02**	**2.15E+02**	**1.64E+02**	**1.81E+02**	**1.28E+02**	**2.34E+02**	**1.61E+02**
	Total incl. D	**2.25E+02**	**2.50E+02**	**2.75E+02**	**2.03E+02**	**2.15E+02**	**1.64E+02**	**1.81E+02**	**1.28E+02**	**2.34E+02**	**1.61E+02**

Whole Building Life Cycle Assessment Reference Building Results for Christchurch Excluding B6 Plug Loads											
Total Primary Energy (MJ) Impact	**Lifecycle Module Stage**	**Z3, Co, S3a**	**Z3, Cx, S3**	**Z3, Co, S3b**	**Z3, Co, S4a**	**Z3, Co, S4b**	**Z3, Cx, S4a**	**Z3, Cx, S5**	**Z3, Co, S5a**	**Z3, Cx, S4b**	**Z3, Co, S5b**
	60 Year										
	A1-A3	4.93E+05	5.38E+05	1.18E+06	2.43E+06	2.09E+06	1.69E+06	4.26E+06	2.81E+06	1.47E+06	4.13E+06
	A4-A5	2.89E+06	2.73E+06	3.72E+06	5.60E+06	3.76E+06	2.95E+06	2.89E+06	1.19E+06	4.09E+06	1.07E+07
	B2, B4	5.14E+07	5.88E+07	2.60E+07	1.49E+08	1.42E+08	1.28E+08	3.65E+08	1.88E+08	1.34E+08	2.20E+08
	B6	5.75E+05	5.60E+05	2.89E+05	1.74E+06	1.51E+06	1.86E+06	4.69E+06	3.13E+06	1.45E+06	3.61E+06
	B7	5.99E+05	7.20E+05	4.66E+05	2.74E+06	2.00E+06	1.88E+06	5.63E+06	3.26E+06	1.56E+06	4.77E+06
	C1-C4	-7.75E+05	-7.28E+05	-7.52E+05	-4.61E+06	-3.40E+06	-1.56E+06	-3.57E+06	-2.92E+06	-1.88E+06	-4.91E+06
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.52E+07**	**6.26E+07**	**3.09E+07**	**1.57E+08**	**1.48E+08**	**1.35E+08**	**3.79E+08**	**1.96E+08**	**1.40E+08**	**2.38E+08**
	Total incl. D	**5.52E+07**	**6.26E+07**	**3.09E+07**	**1.57E+08**	**1.48E+08**	**1.35E+08**	**3.79E+08**	**1.96E+08**	**1.40E+08**	**2.38E+08**
	Lifecycle Module Stage	**Z3, Co, S3a / m² GFA / year**	**Z3, Cx, S3 / m² GFA / year**	**Z3, Co, S3b / m² GFA / year**	**Z3, Co, S4a / m² GFA / year**	**Z3, Co, S4b / m² GFA / year**	**Z3, Cx, S4a / m² GFA / year**	**Z3, Cx, S5 / m² GFA / year**	**Z3, Co, S5a / m² GFA / year**	**Z3, Cx, S4b / m² GFA / year**	**Z3, Co, S5b / m² GFA / year**
	A1-A3	4.06E+00	4.64E+00	1.09E+01	5.19E+00	5.90E+00	4.41E+00	3.10E+00	4.31E+00	3.70E+00	5.20E+00
	A4-A5	2.38E+01	2.35E+01	3.42E+01	1.20E+01	1.06E+01	7.71E+00	2.10E+00	1.83E+00	1.03E+01	1.35E+01
	B2, B4	4.24E+02	5.07E+02	2.39E+02	3.19E+02	3.99E+02	3.34E+02	2.66E+02	2.89E+02	3.36E+02	2.76E+02
	B6	4.74E+00	4.83E+00	2.66E+00	3.71E+00	4.26E+00	4.86E+00	3.41E+00	4.81E+00	3.65E+00	4.55E+00
	B7	4.94E+00	6.21E+00	4.28E+00	5.86E+00	5.63E+00	4.91E+00	4.09E+00	5.00E+00	3.92E+00	6.00E+00
	C1-C4	-6.39E+00	-6.28E+00	-6.91E+00	-9.86E+00	-9.57E+00	-4.07E+00	-2.60E+00	-4.48E+00	-4.74E+00	-6.18E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**4.55E+02**	**5.40E+02**	**2.84E+02**	**3.36E+02**	**4.16E+02**	**3.52E+02**	**2.76E+02**	**3.00E+02**	**3.53E+02**	**2.99E+02**
	Total incl. D	**4.55E+02**	**5.40E+02**	**2.84E+02**	**3.36E+02**	**4.16E+02**	**3.52E+02**	**2.76E+02**	**3.00E+02**	**3.53E+02**	**2.99E+02**
	Lifecycle Module Stage	**Z3, Co, S3a / m² NLA / year**	**Z3, Cx, S3 / m² NLA / year**	**Z3, Co, S3b / m² NLA / year**	**Z3, Co, S4a / m² NLA / year**	**Z3, Co, S4b / m² NLA / year**	**Z3, Cx, S4a / m² NLA / year**	**Z3, Cx, S5 / m² NLA / year**	**Z3, Co, S5a / m² NLA / year**	**Z3, Cx, S4b / m² NLA / year**	**Z3, Co, S5b / m² NLA / year**
	A1-A3	4.88E+00	5.46E+00	2.33E+01	7.95E+00	7.87E+00	5.16E+00	5.17E+00	5.10E+00	5.76E+00	6.50E+00
	A4-A5	2.86E+01	2.77E+01	7.32E+01	1.83E+01	1.41E+01	9.02E+00	3.51E+00	2.16E+00	1.60E+01	1.69E+01
	B2, B4	5.08E+02	5.97E+02	5.11E+02	4.88E+02	5.33E+02	3.91E+02	4.44E+02	3.42E+02	5.23E+02	3.45E+02
	B6	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00	5.69E+00
	B7	5.92E+00	7.31E+00	9.16E+00	8.97E+00	7.52E+00	5.75E+00	6.83E+00	5.91E+00	6.10E+00	7.51E+00
	C1-C4	-7.67E+00	-7.39E+00	-1.48E+01	-1.51E+01	-1.28E+01	-4.76E+00	-4.33E+00	-5.30E+00	-7.38E+00	-7.73E+00
	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total excl. D	**5.46E+02**	**6.36E+02**	**6.08E+02**	**5.14E+02**	**5.55E+02**	**4.12E+02**	**4.60E+02**	**3.56E+02**	**5.50E+02**	**3.74E+02**
	Total incl. D	**5.46E+02**	**6.36E+02**	**6.08E+02**	**5.14E+02**	**5.55E+02**	**4.12E+02**	**4.60E+02**	**3.56E+02**	**5.50E+02**	**3.74E+02**