CRC Construction Innovation

BUILDING OUR FUTURE

Final Report
Tasks 1 and 4: Eco-Efficiency Assessment of Building Refurbishment

Research Project No: 2003-028-B-T1-01

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ACKNOWLEDGEMENTS

Stephen Webb of Design Inc supplied the essential and comprehensive 3D CAD model of the structure of the existing building to which some fitout features (e.g. internal walls) were added. P.C. Thomas of Arup Pty Ltd supplied the NABERS assessment of the existing building.

EXECUTIVE SUMMARY

Objectives

The main objective was to compare the environmental impacts of a building undergoing refurbishment both before and after the refurbishment and to assist in the design of the refurbishment with what is learned. The specific objectives as modified due to the lack of a refurbished building were to:

- Review the issues of reuse for the Council House 1 Building, and
- Provide a quantitative assessment to
  - Compare the environmental impact of the whole building using existing materials with the same building if was built today using preferred materials, and.
  - Include recycled content where possible in the assessment.

Outline of project

The supplied 3D CAD model of the existing building was modified and assessed using LCADesign which required some modifications to match the materials in the existing building at the required level of detail. The tasks included:

- Refinement of the 3D model as required,
- Improvements to LCADesign to incorporate measures of refurbishment (i.e. the parts of the building which can changed in the refurbishment design compared to those components which remain static from the first 3D CAD model),
- Extension of the Life Cycle Inventory database for new materials/components,
- Creation of additional reasoning rules for refurbishment activities, and
- Analysis of the results.

Findings

The project was unable to compare the pre versus post refurbishment at a whole building level and relevant sub-system level for the designated Council House 1 building as the refurbishment of the building was postponed for some years. However, LCADesign was used to analyse the existing Council House 1 and set up the modifications to LCADesign for application to a refurbished building. A preliminary NABERS assessment of the existing building was undertaken and provided to this project but no GreenStar assessment was done on the existing building due to the high cost of the assessment.

It was clearly shown that an existing 3D CAD model could be easily adapted to the needs of LCADesign by adding additional objects as required. A measure of recycled content was added to LCADesign with the required recycled content of every product used being readily added to each Product Reasoning Rule.

A methodology was developed, data gathered and provision made in LCADesign for comparing the environmental impacts of the new, retained and demolished components of a building but no comparisons were made due to the lack of a refurbished building with which to compare the existing Council House 1.

A completely new database of Object and Product Reasoning Rules was created to make the products used specific to Council House 1 and to provide for alternative products which have lower environmental impact and were expected to be used in the refurbishment. The development of a specific database made it much easier to tag the 3D CAD model and provide clear alternative products. This approach should be followed up in any redeveloped version of LCADesign.

The Boustead Life Cycle Inventory model was updated to representative Australian products used in construction of the Council House 1 building along with estimates of the use of recycled materials during the manufacture of these products. The result was a new but

limited LCI database specifically targeted towards the products used in the Council House 1 Building and its proposed refurbishment. The additional products with lower environmental product provided the opportunity to compare the impacts of using alternative products.

The use of 3D CAD models provide an excellent starting point for application of Life Cycle Analysis to buildings and LCADesign has the potential to be a unique tool for analysis of buildings at the design stage for both new buildings and refurbished buildings. The extension to refurbished buildings fitted very well within the framework previously developed for new buildings.

Implications for industry and community

Recycled content can now be estimated for use in other rating schemes such as GreenStar. However, it should be noted that the available data is not comprehensive or reliable. Significant effort will be required to produce data that is accurate across the industry.

An example of use of alternative building products with lower environmental impact showed that the Eco-indicator 99 score could be reduced by up to 20% (?). The major contributors to the Eco-indicator 99 score were the upper floors (columns, slabs and beams of the structure) followed by the floor finishes (predominantly carpet), the internal walls and external walls. As is typical of buildings, the ecosystem quality measure makes a much smaller contribution than the resource consumption and the human health indicators.

While the overall indicator, Eco-indicator 99 (and others), decreased, the embodied energy component rose, driven by the big increase in the scenery (fittings) component. As expected the recycled mass also rose sharply as a result of using 99% recycled reinforcement bars and concrete with a 7% flyash content. There appears to be a correlation between the increasing ruse of recycled material and reduced environmental impact as measured by Eco-indicator 99.

The use of 3D CAD models provide an excellent starting point for application of Life Cycle Analysis to buildings and LCADesign has the potential to be a unique tool for analysis of buildings at the design stage for both new buildings and refurbished buildings. The extension to refurbished buildings fitted very well within the framework previously developed for new buildings.

Further research

A completely new database of Object and Product Reasoning Rules was created to make the products used specific to Council House 1 and to provide for alternative products which have lower environmental impact and were expected to be used in the refurbishment. The development of a specific database made it much easier to tag the 3D CAD model and provide clear alternative products. This approach should be followed up in any redeveloped version of LCADesign.

As a result of the use of LCADesign on Council House 1, a number of suggestions for improving LCADesign were identified, in addition to those which were necessary to undertake the analyses required for this project, as listed below:

- The ArchiCAD addin (or proposed viewer tagging) should allow for tagging multiple Object Reasoning Rules to each object.
- The ArchiCAD addin (or proposed viewer tagging) should provide for an additional attribute for each object tag for identifying whether the object is new, retained or demolished.
- The Reasoning Rule Manager should be integrated with LCADesign.
- The data on recycled content should be in the LCI database and derived directly from the LCI model not added via the Reasoning Rule Manager.
- The results of the recycled content analysis should be displayed in the LCADesign graphs in a similar manner to the existing environmental factors.
- There should be a facility to import Reasoning Rules into one database from another database.

- Calculating and display of the proportions of the building which are new, retained or demolished should be completed.

1 INTRODUCTION

1.1 Background

The focus of development in the built environment is moving from “demolish and rebuild” to refurbishment as increasing acknowledgement is made of the social, cultural and economic benefits of refurbishing appropriate existing buildings rather than bulldozing them. Such refurbishment projects generally include a range of Environmentally Sustainable Development (ESD) goals. Benefits include less impact and reductions in energy, water, waste and indoor environment (health and productivity of occupants). Recycling older buildings for reuse is recognised as a good approach to minimisation of consumption of resources.

Regenerating Construction to Enhance Sustainability is a Cooperative Research Centre for Construction Innovation project designed to assist Melbourne City Council to deliver a superior refurbished building, known as Council House 1 (CH1), according to a core set of sustainability criteria. These are:

- Eco-efficiency: minimising the ecological footprint of the refurbished building (compared to predecessor) within an agreed budget,
- High quality indoor environment: where the refurbished building has achieves demonstrable improvement in respect of key Indoor Environment Quality criteria, including thermal performance and indoor air quality, reflected in improved health, well-being and productivity of building occupants,
- Healthier and more productive working environment: as measured by performance of occupants pre- versus post- refurbishment, and
- Waste minimisation: The AEC-FM industry contributes a significant proportion of the waste that goes into Australian land fill sites. The major peaks in waste generation occur in two distinct phases of the building life cycle - initial construction and refurbishment/ demolition. This task examines how to reduce the generation of waste during construction, i.e. off-cuts, over ordering, etc, and refurbishment, by increasing recycling and re-use. Dual objectives relate to minimisation of construction waste during refurbishment and minimisation of waste generation during next refurbishment (or demolition) phase as a result of designing for dis-assembly during the current refurbishment

These are all quantifiable elements, the results of which could be employed to estimate the contribution of refurbishments (to prescribed levels) to improved Triple Bottom Line performance of the entire built environment. The project focused on four key tasks:

- **Task 1**: Use of assessment tools for building redesign (original versus refurbished building) to assist industry with respect to benchmarking practice and harmonisation of current Australian assessment tools.
- **Task 2**: Developing design guidelines for delivering high quality indoor environments and protocols for their measurement.
- **Task 3**: A before versus after survey of building occupant health, well-being and productivity, in order to value the benefit of enhanced indoor environments. Tasks 2 and 3 need to be undertaken on the same refurbished building.
- **Task 4**: A prototype tool developed for use in association with 3D CAD that can assess material selection on the basis of ease of dis-assembly, re-use and recycling (thereby minimising waste generation in subsequent refurbishment or demolition.

This report covers **Tasks 1 and 4** of the four key tasks being undertaken on Council House 1 and documents the scope of the LCADesign assessment, related end-of-life/reuse/recycling issues of public buildings, significant issues that arise in the assessment and any specific LCADesign methodologies required to complete the Council House 1 assessments.

1.2 Task 1 - Eco-efficiency assessment of building refurbishment

Three "green" building tools currently exist in Australia with a capacity to undertake before versus after refurbishment assessment to varying levels of quantifiable criteria. The main focus of Task 1 was on assessment using LCADesign, but it was also planned to utilise GreenStar and NABERS evaluations done by others for the client's (Melbourne City Council's) existing and re-designed building. These were to provide performance assessments across a range of key domains (e.g. water, energy, waste, indoor environment etc) during re-design and post-occupancy, as outlined in Table 1 below. The shaded blocks indicate what was to be covered in Task 1.

Table 1 Application of existing environmental assessment tools

	Original performance of building as a product - materials	**Re-design performance of building as a product - materials**	**In-service performance of building as operated**	**Redesigned in service performance of building as operated**
LCADesign	✓	✓		
Green Star			✓	✓
NABERS			✓	✓

As it turned out, the high cost of undertaking GreenStar evaluations was not justifiable to the client and all but one assessment did not occur. A NABERS assessment was undertaken for the existing building as part of another project and the results made available to this project.

Task 1 required a 3D CAD model of the building as it currently stands as an essential prerequisite to ensure it can be analysed using LCADesign. A comprehensive 3D CAD model of the existing building structure was provided by Design Inc.

The Melbourne City Council decided in 2006 that the refurbishment component of this study would be postponed for up to five years. Although there was a recommended option for refurbishment, using it would not satisfy the need to assess an actual building. Thus Task 1 was restricted to the assessing the existing building and could not address the topic of reuse for refurbishment. Since eco-preferred materials were included in the Life Cycle Inventory developed for the LCADesign assessments, it was decided to compare the whole building using existing materials with the same building if was built today using preferred materials – a function which is easily undertaken in LCADesign.

1.3 Task 4 – Waste Minimisation in Design

The concepts of design for disassembly are well understood and fit well with the goal of reducing the environmental impact of building construction activity. These concepts need to be considered within an overarching framework for design for disassembly (Figure 1-1).

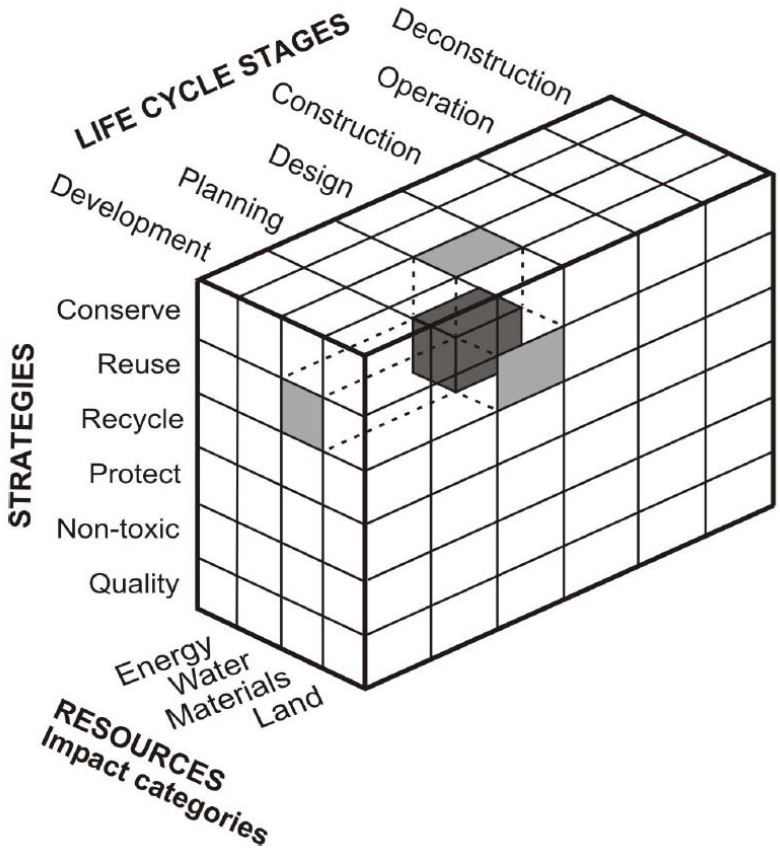


Figure 1-1: Design for Disassembly Framework (Crowther)

Design for disassembly is built around the concept of “layers” as illustrated in Figure 1-2. Each layer supports other layouts depending on the longevity of the components in that layer with respect to the supported layer. Longevity is (hopefully) only a measure of how long a component is in a particular place rather just time to replacement and/or disposal.

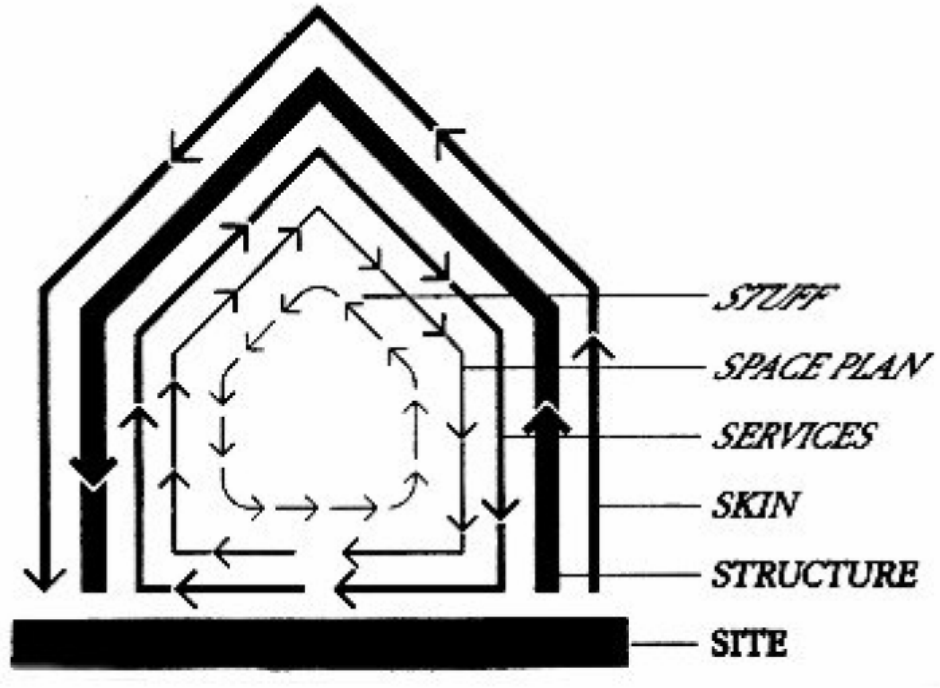


Figure 1-2: Buildings as "layers" (Brand, 1994)

The lifecycle of building components is show in Figure 1-3.

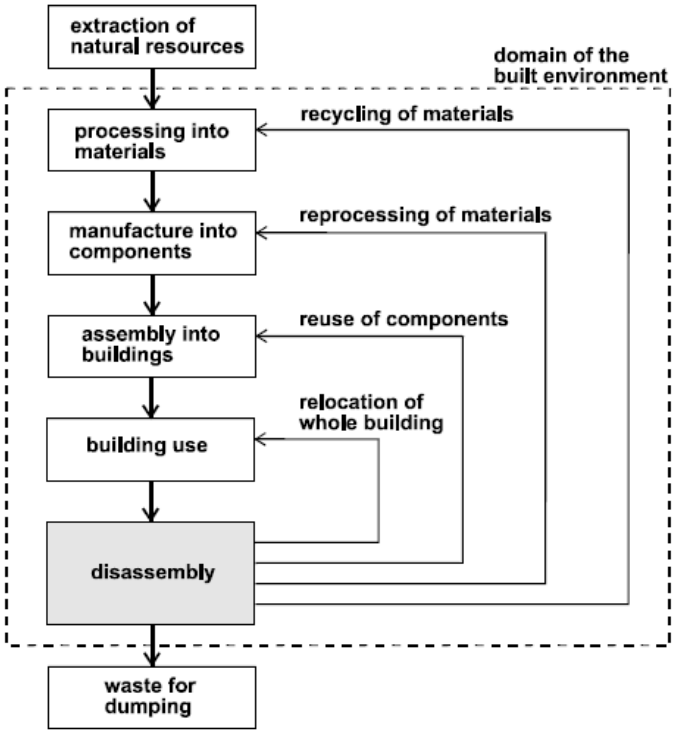


Figure 1-3: Component life cycle and "end of life" scenarios (Crowther)

The concept of “layers” is already covered in LCADesign, as are the environmental impacts of the processes up to and including “assembly into buildings”.

The initial report prepared for this project (Appendix IV -) describes the guidelines that should be considered in a project such as CH1.

As noted by the team working on Task 1, LCADesign should be extended to incorporate design for disassembly factors as part of its standard user interface. The existing software architecture is capable of supporting this. The only significant change is the addition of “Design for Disassembly” as a factor on the left hand side of the “measures” screen within LCADesign.

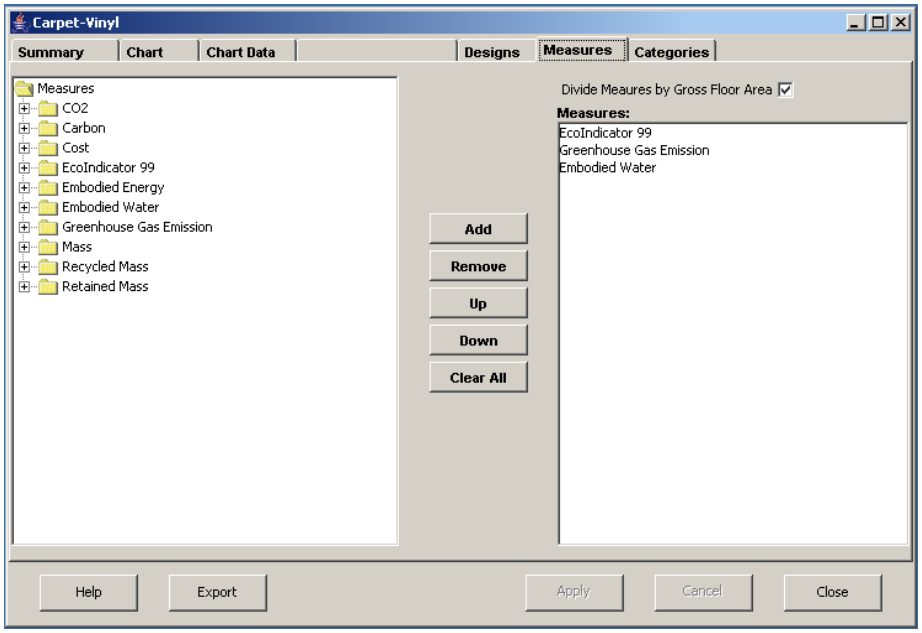


Figure 1-4: Measures screen in LCADesign

1.4 Re-use/Recycling results

The results of the data gathering undertaken by the University of Western Sydney team are shown in Figure 1-5 - Figure 1-8. While stringent efforts were made to gather the best possible data for this project its is very difficult to obtain accurate data from the companies working in the refurbishment/demolition area due to the lack of incentives for them to accurately measure the proportion of material going into each waste stream.

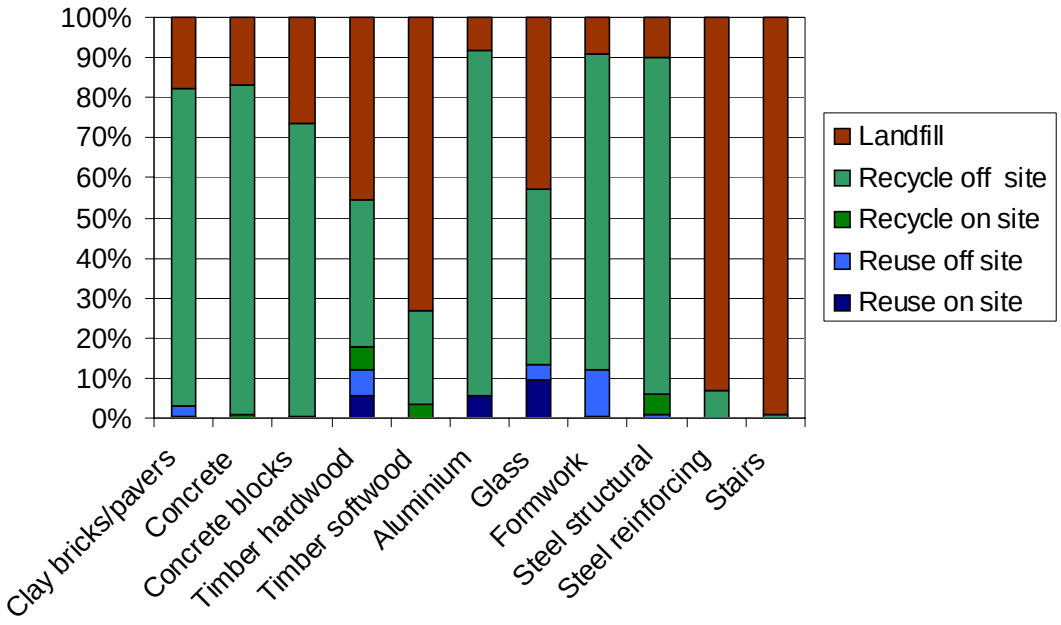


Figure 1-5: Destination of Building Fabric Components

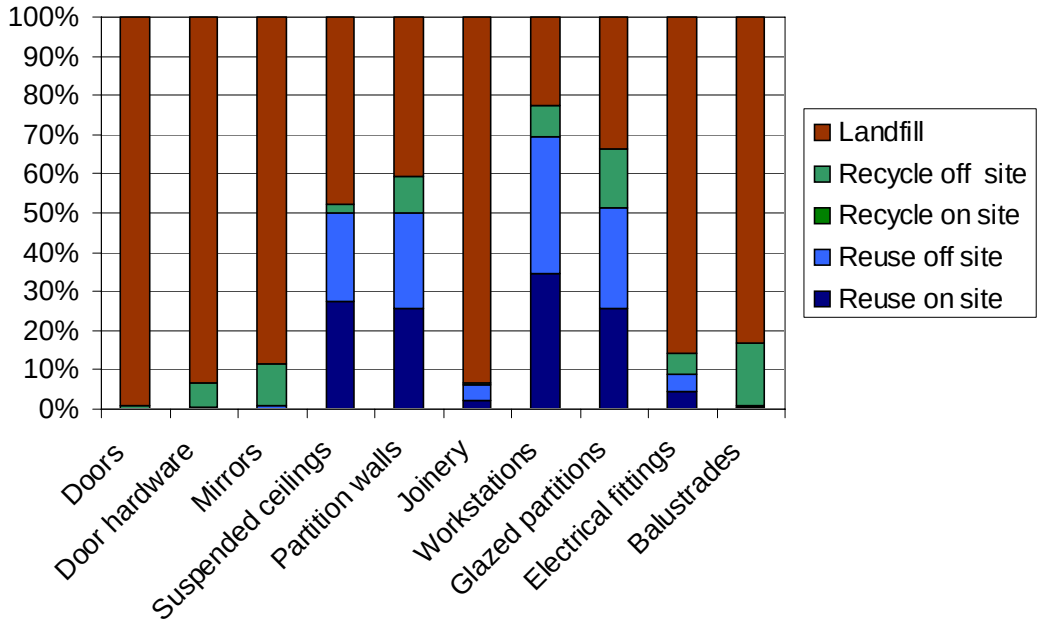


Figure 1-6: Destination of Fittings Components in

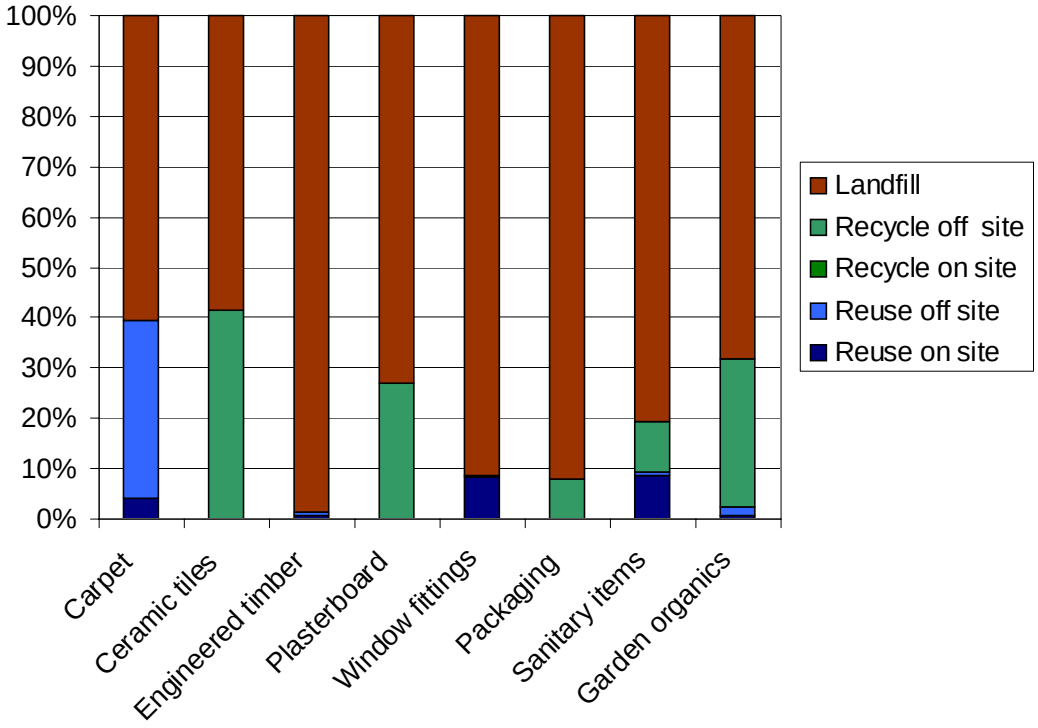


Figure 1-7: Destination of Finish Components

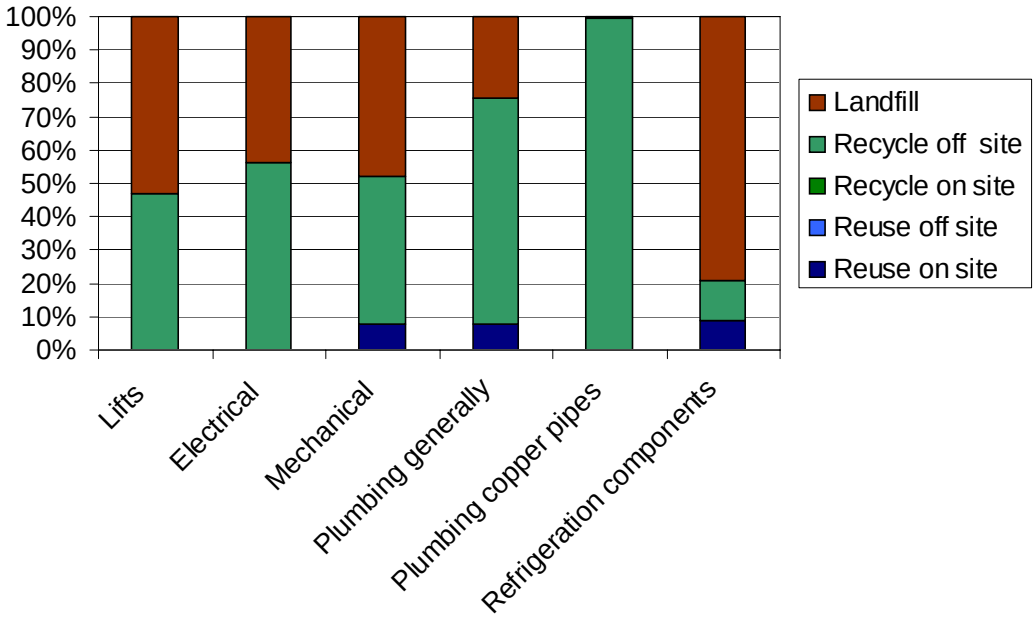


Figure 1-8: Destination of Services Components

1.5 Assessment objectives

The main objective was to compare the environmental impacts of the building undergoing refurbishment both before and after the refurbishment and to assist in the design of the refurbishment with what is learned.

The LCADesign assessment team objectives were to:

- Assess the issues of reuse for the Council House 1 Building, and
- Provide a quantitative assessment to
  - Assess how much of a saving on impacts there is through reuse, and
  - Assist design selections for new elements as relates to associated recycle-ability and recycled content issues.

These two quantitative assessments were to be measured as ***regeneration potential*** and ***recycle-ability***.

The modified objectives became:

- Review the issues of reuse for the Council House 1 Building, and
- Provide a quantitative assessment to
  - Compare the environmental impact of the whole building using existing materials with the same building if was built today using preferred materials, and.
  - Include recycled content where possible in the assessment.

1.6 Assessment aims

It is important to understand the environmental intents and their priorities to ensure the process of environmental assessment is focussed on providing meaningful outcomes. Due to the broad applications of LCADesign and standard LCA assessments, it is essential to ensure understanding of intent before developing methodologies and generating outputs. Clarifying the environmental intents assists to sets boundaries to the study and define the criteria most relevant to the examination.

Improvements to the LCADesign software were implemented to incorporate refurbishment measures. The refurbishment assessment was undertaken in order to assess:

- The possible reduction in the environmental impact of the CH1 building if the same building was built today,
- Clarify what aspects of reuse/recyclability need to be addressed, and
- Compare design alternatives against quantitative benchmarks/performance targets.

1.7 LCADesign

LCADesign, a prototype Building Environmental Assessment (BEA) tool, was used to assess end-of-life, reuse and recyclability potentials (i.e. regeneration potentials) of Melbourne City Councils' Council House 1 (CH1) building.

The LCADesign prototype, which was developed through the Cooperative Research Centre for Construction Innovation (CRC CI), links 3-dimensional CAD information with an Australian Life Cycle Inventory (LCI) database of building products to assess environmental impacts using international standard Life Cycle Impact Assessment (LCIA) methods and models. LCADesign assesses potential environmental impacts and is also can be used as a general decision support tool for environmental decisions relating to construction of buildings. It is currently used for Australian commercial buildings with the exception of demonstration buildings in the Netherlands and the United States..

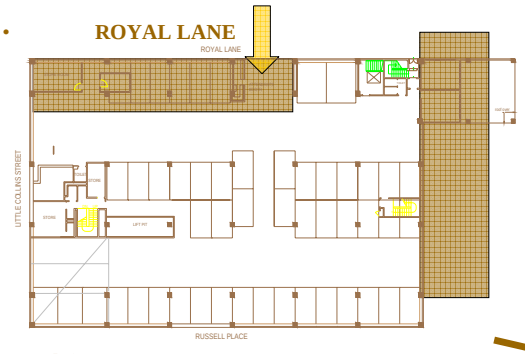
The capabilities of LCADesign were expanded to include the associated sustainability issues of preferred materials and recycled content of materials in the Melbourne Council House 1.

2 COUNCIL HOUSE 1

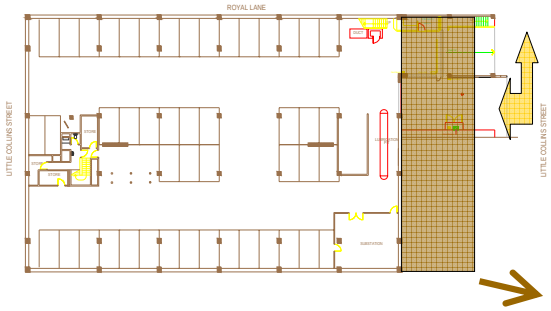
2.1 Building description

Council House 1 is an existing multistorey building at 200 Little Collins Street in Melbourne and owned by the Melbourne City Council. The site is bounded by Royal Lane, Russelll Place and the Commonwealth Bank Building at 225 Bourke Street. The site runs on a north-south axis and has a surface area of 1960 m^2. There are three floors of car park for 230 cars, a retail area of 400m^2, offices on seven floors each of 1070m^2 per floor totalling 7490m^2 and roof level plant room. An external view of the building is shown in Figure 2-1 and the floor plans are shown in Figure 2-2. Some views of the interior a re shown in Figure 2-3.

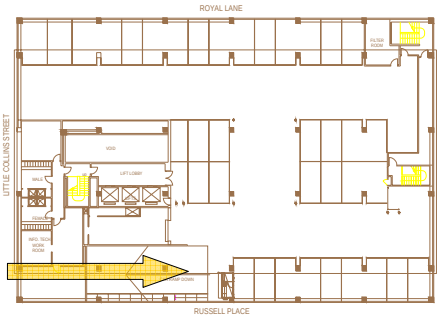
Figure 2-1 External view of Council House 1



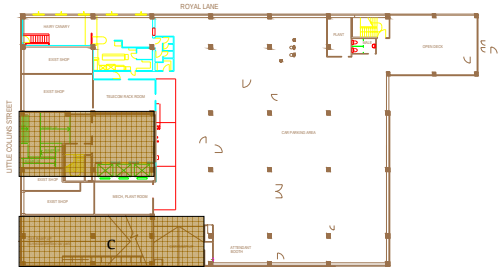
- **ROYAL LANE**
- **BASEMENT LEVEL**
- with entrance from Royal lane



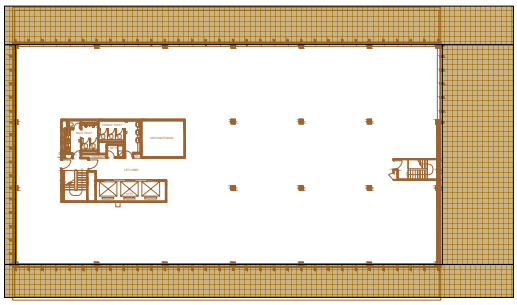
- **PLAN OF LOWER BASEMENT**
- corporate car park with access from Royal Lane



- **MEZZANINE LEVEL**
- showing upper level car park with entrance from Little Collins street

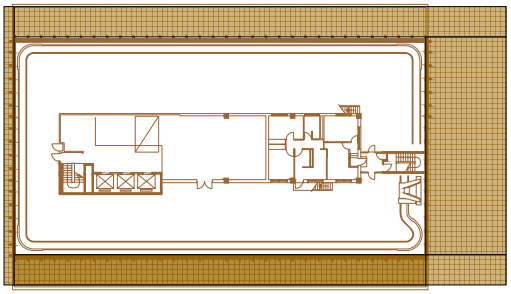


- **GROUND FLOOR LEVEL**
- showing entrance from Little Collins Street showing how much space is taken by car park entrances.



Typical floor plan, NLA=1070m2 X 7 = 7490m2

There are seven floors thus with potential extension areas shown in brown hatch



Roof plan showing plant rooms

Figure 2-2 Floor plans of each level of Council House 1

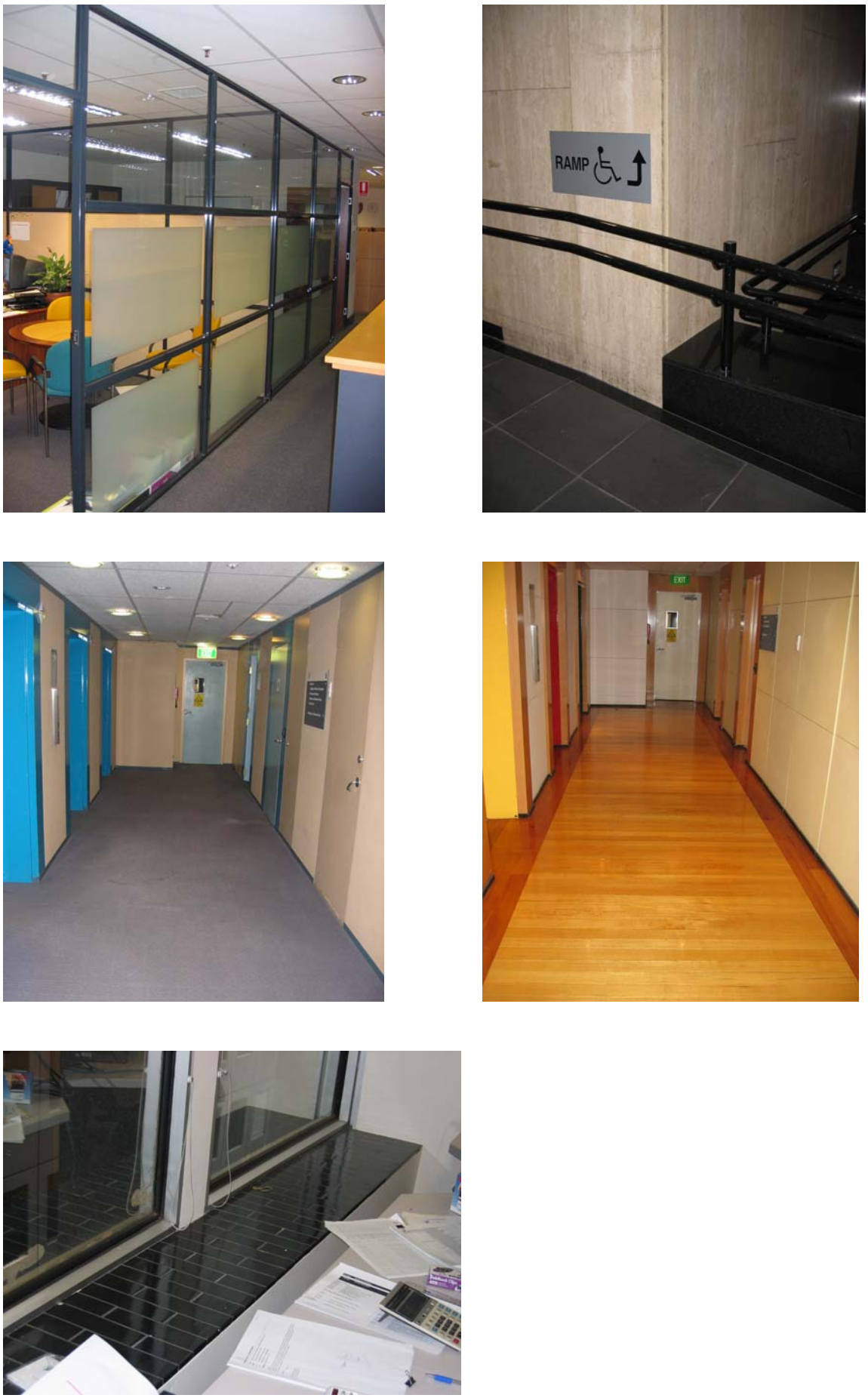


Figure 2-3 Internal views of Council House 1

The structure is a concrete sway frame with horizontal bracing required at gable ends or between columns in one southern bay. The core walls are not structural. Floor to floor height is 3150mm with a slab thickness of 235mm, with a down-stand beam in the core area of 465mm which gives a clearance of 2450mm. There is an up-stand beam around the perimeter of 560mm.

Windows are formed within pre-cast façade units of size 3150mm H X 1565mm W and have a glass area of 2110mm H X 1380mm W. This gives a glass area of 69% of the total façade area. The west side glass is covered with a reflective film which is coming off. The roof covering needs replacing and the lower basements leak badly. All services installation need replacing.

2.2 3D CAD modelling

The structure of the existing building has been drawn as a 3D CAD model in ArchiCAD as illustrated in Figure 2-4. Figure 2-5 shows alternate views of the front and rear of Council House 1. Each pre-cast façade unit (see detail in Figure 2-6) had to be drawn individually, making the 3D CAD model very extensive in terms of objects.

The ArchiCAD model of CH1 is an early schematic design stage showing the two basements, main ground level and mezzanine and seven typical floors, and the plant room on the roof. All structural elements such as columns, slabs, roof and walls are drawn in the 3D CAD model. Staircases are included. All interior walls and doors (such as illustrated in Figure 2-6) are included as shown in the floor plans and in Figure 2-7. The floor plans are as shown in Figure 2-8 to Figure 2-20.

Sanitary facilities are included in the model but the associated hydraulic services are not built and neither are HVAC items in the model. The model is considered an elaborate envelope model only, suitable for early schematic design stage primarily to support early architectural design decisions.

The proposed refurbished building was planned to have one floor of retail space at ground level, nine floors of office space and three floors of parking.

Figure 2-4 ArchiCAD 3D CAD View of Council House 1

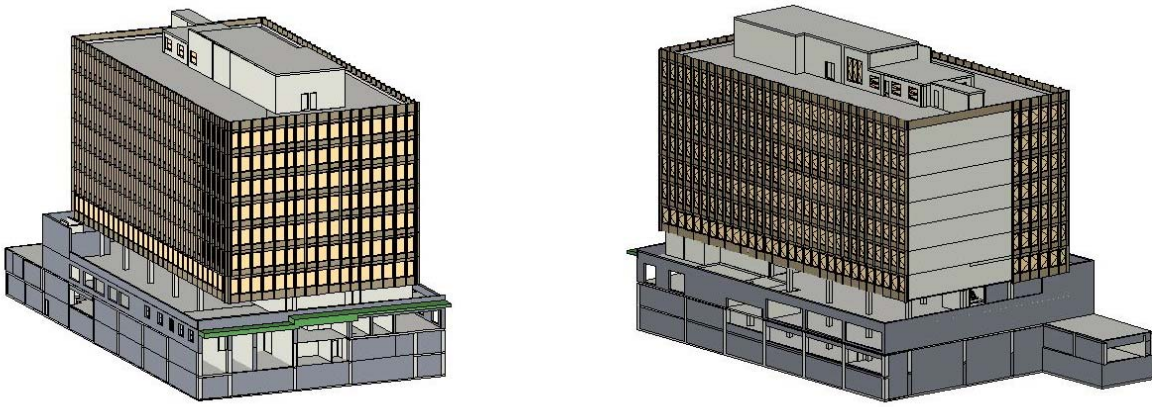


Figure 2-5 ArchiCAD 3D CAD front and rear Views of Council House 1

Figure 2-6 External detail of wall elements and internal walls included in the 3D CAD model of Council House 1

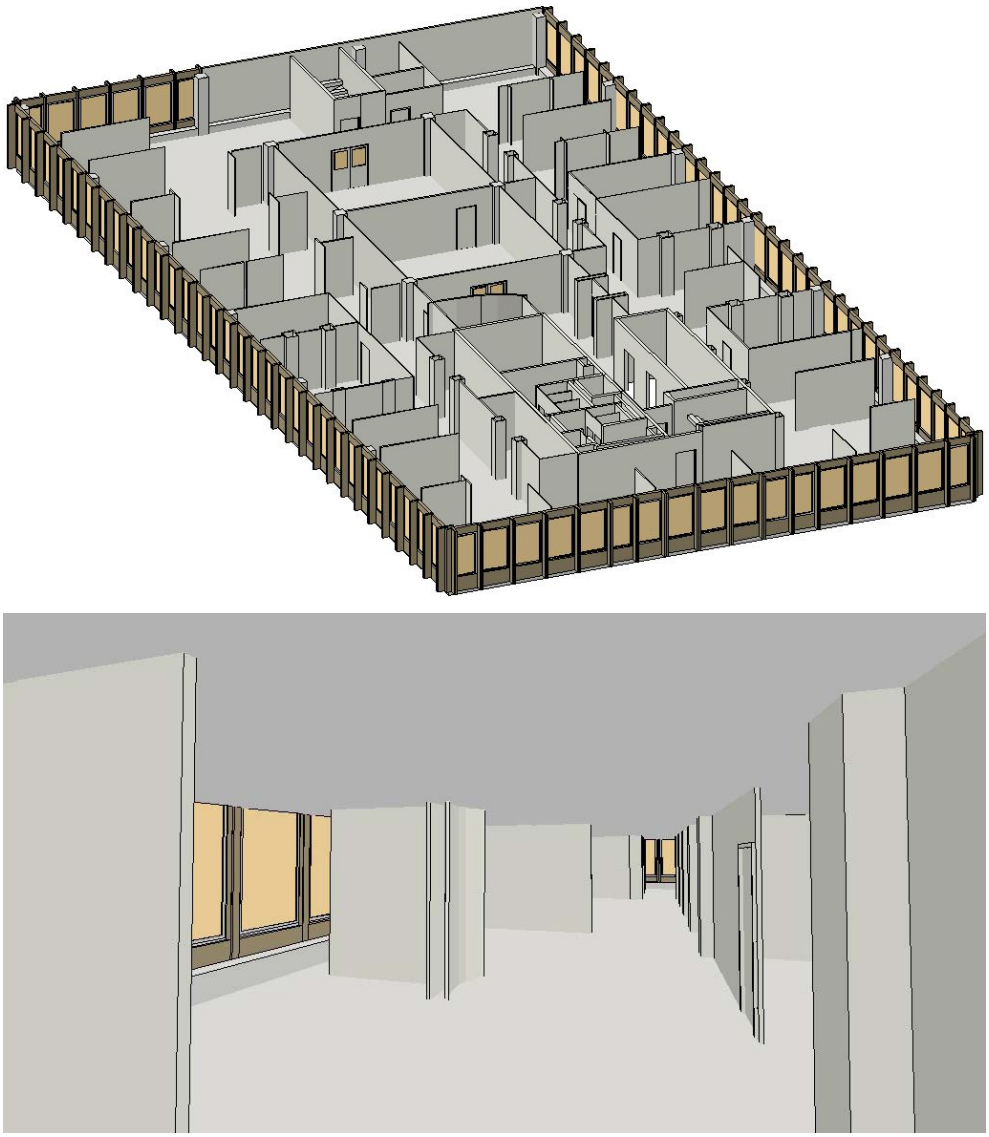


Figure 2-7 ArchiCAD 3D CAD Views of a single floor of Council House 1

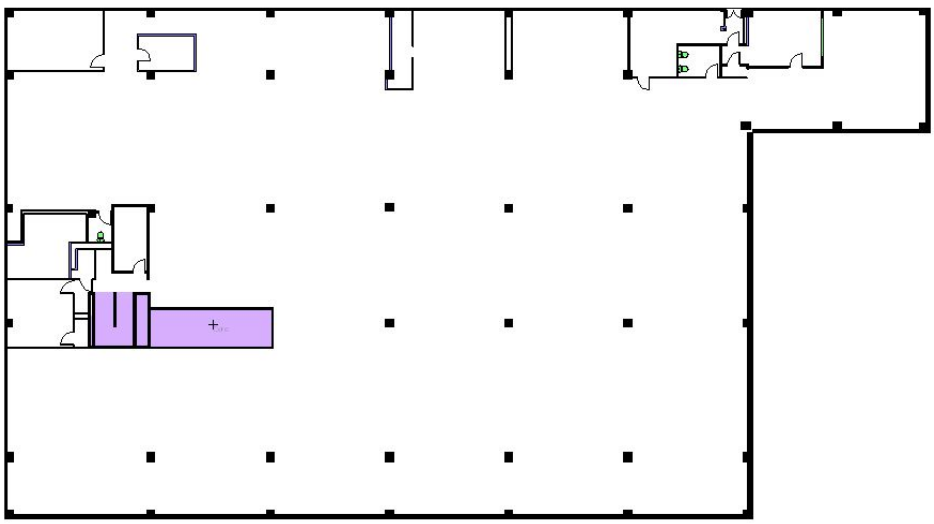


Figure 2-8 ArchiCAD floor plan of basement level of Council House 1

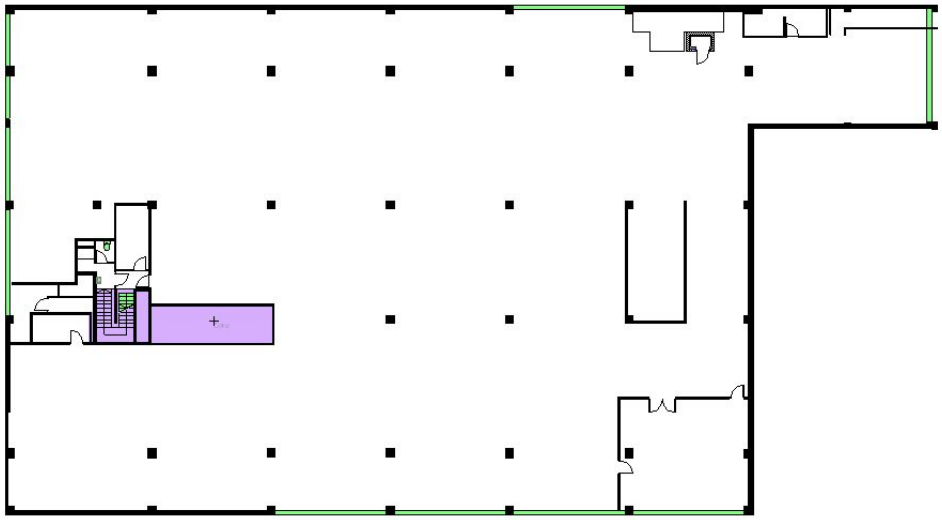


Figure 2-9 ArchiCAD floor plan of corporate car park level of Council House 1

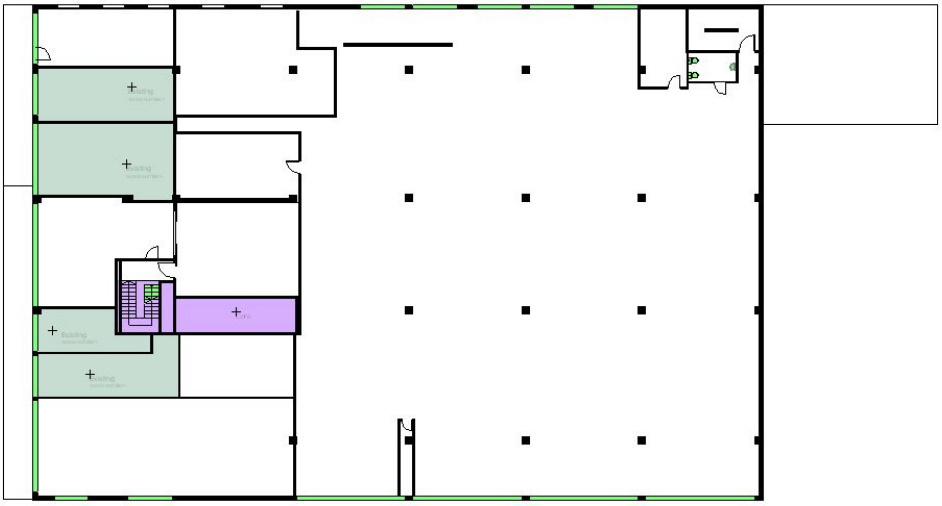


Figure 2-10 ArchiCAD floor plan of ground floor of Council House 1

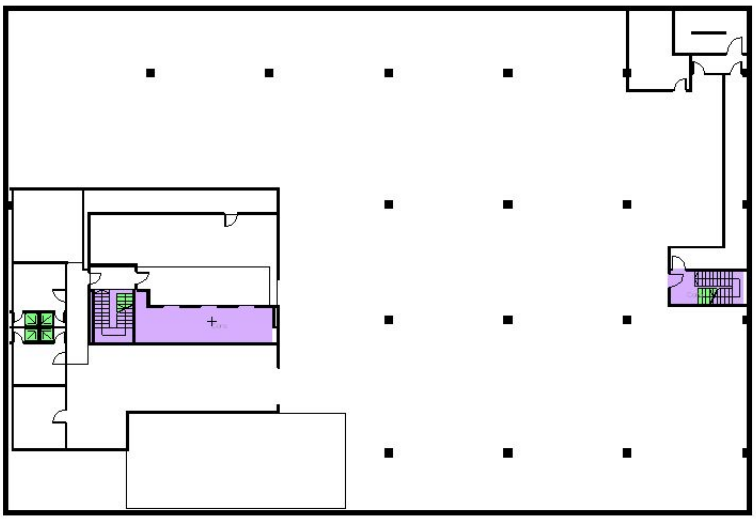


Figure 2-11 ArchiCAD floor plan of mezzanine level of Council House 1

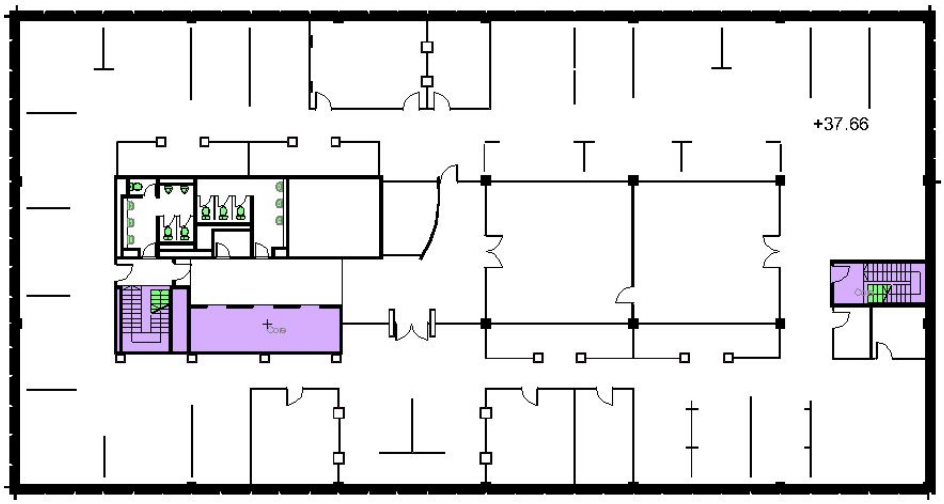


Figure 2-12 ArchiCAD floor plan of first floor of Council House 1

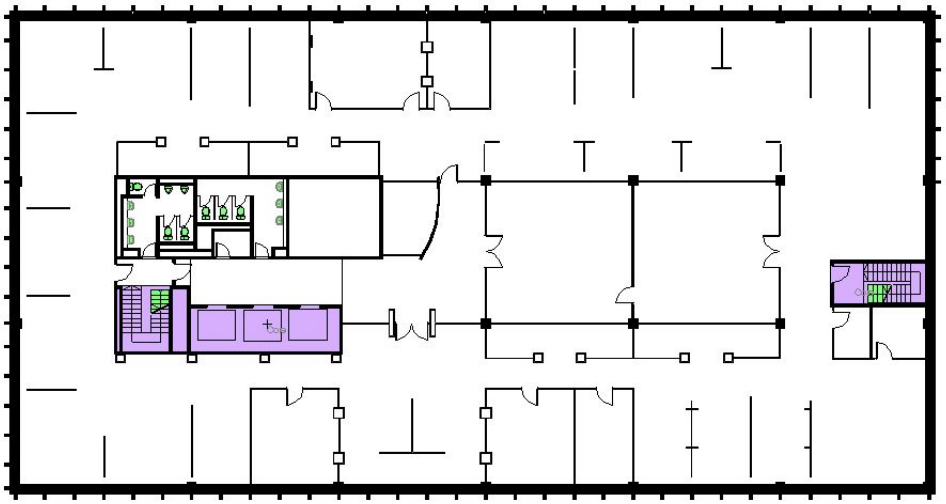


Figure 2-13 ArchiCAD floor plan of second floor of Council House 1

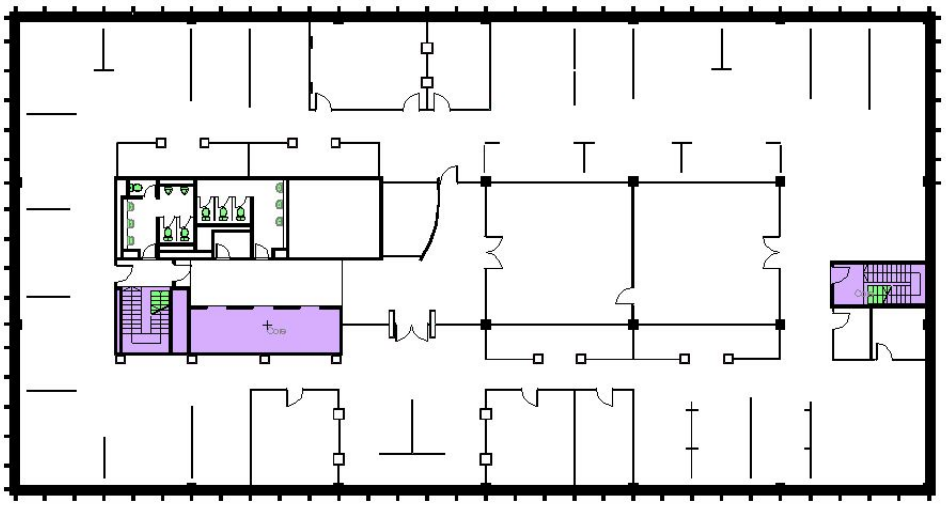


Figure 2-14 ArchiCAD floor plan of third floor of Council House 1

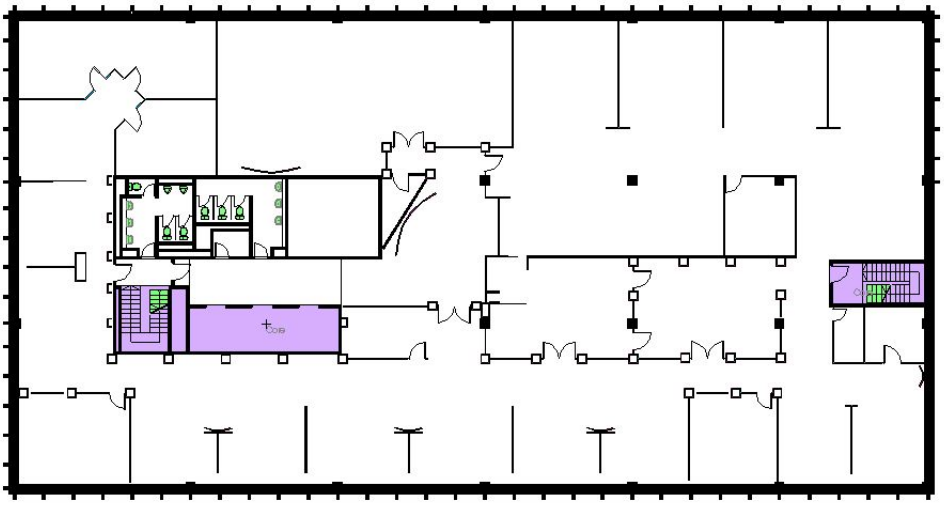


Figure 2-15 ArchiCAD floor plan of fourth floor of Council House 1

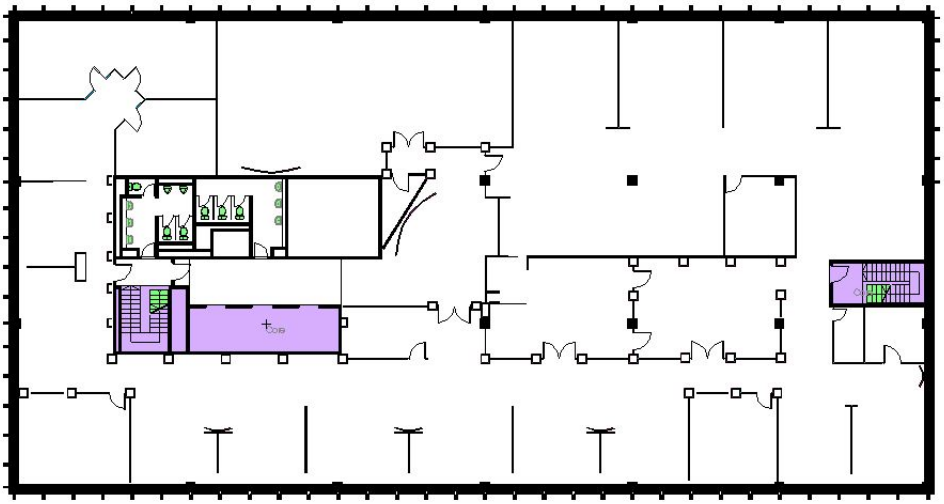


Figure 2-16 ArchiCAD floor plan of fifth floor of Council House 1

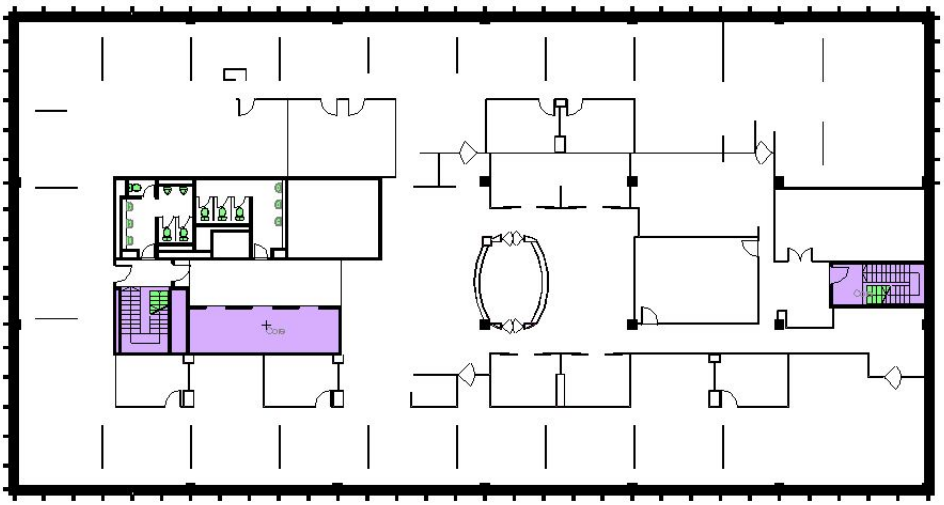


Figure 2-17 ArchiCAD floor plan of sixth floor of Council House 1

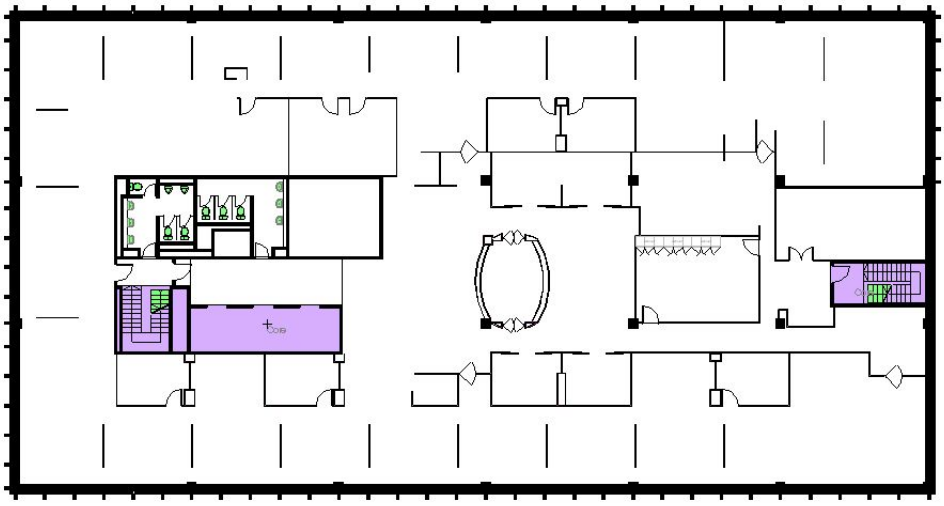


Figure 2-18 ArchiCAD floor plan of seventh floor of Council House 1

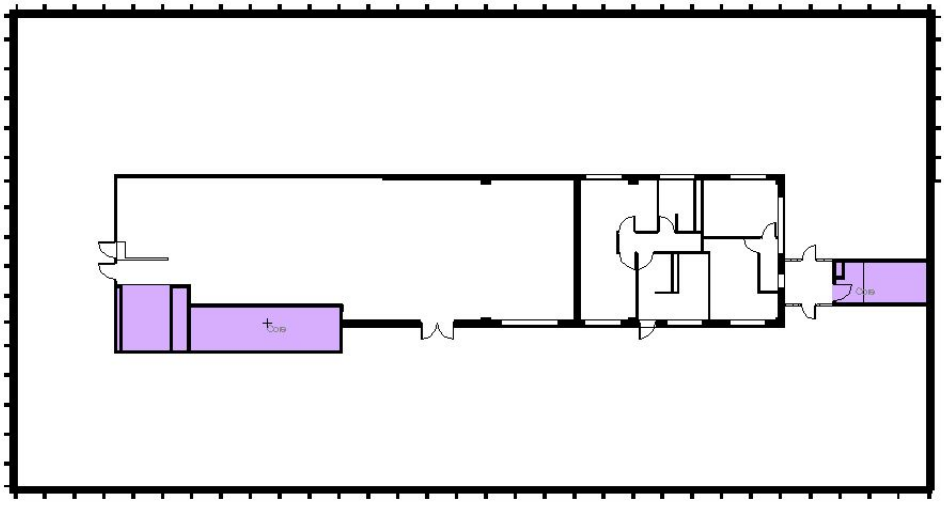


Figure 2-19 ArchiCAD floor plan of eigth floor of Council House 1

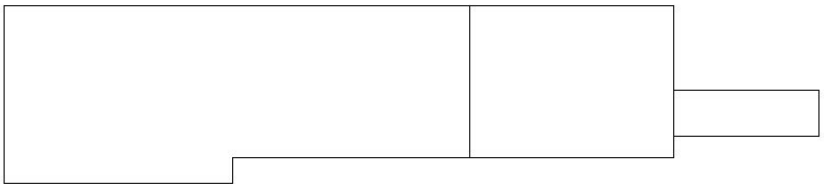


Figure 2-20 ArchiCAD floor plan of roof level of Council House 1

3 REGENERATION OF BUILDINGS

The regeneration of a building implies reuse of significant amounts of the building. A commitment to recycling, whether it be the entire building or parts of it, is also implied.

Regeneration relies upon consideration, assessment and incorporation of a number of end-of life building/component issues such as reuse, recycling and disposal. Key concepts relating to such issues are defined in lists in this section.

As many recycling, reuse and fate at end-of-life concepts are complex, stakeholders may misunderstand or be confused by such language. It is, therefore, important to clarify such terminology to support their consideration in building regeneration. This requires development and provision of clear definitions as listed in the following section.

3.1 Definitions and meanings

To avoid permanently depleting the earth's finite resources, sustainability aims to ensure that material life cycles can continue undiminished and to avoid sending any resource to landfill.

'End-of-life potential' (for the purposes of this project) describes the concept that you can predict the end-of life scenarios for a building. Coupled with the concept of the end-of-life potential scenarios is the concept of reuse, recycling and regenerating the resources used in the original building for another cycle or life. This means that the aim is to recycle, reuse and maintain resources within product supply chains. It supports continuing availability of reusable and recyclable resources and moves towards the goals of sustainability.

The terms discussed in this section are generally applicable to whole buildings, components, products as well as construction and reuse processes.

3.1.1 Important terms

Regeneration, most commonly used to refer to urban and industrial land, is the:

> *'Renewal of sites or habitats that have become unfit for human, animal, or plant habitation to bring them back into productive use. '* (Gissen, 2002)

Reuse (e.g. glass bottles) is described as

> *'The recovery of a material for additional use without reprocessing* (Mendler and Odell, 2000)

Recycle refers to the reoccurrence of a cycle and is described as:

> *'Collecting and reprocessing a resource so it can be used again. An example is collecting aluminium cans, melting them down, and using the aluminium to make new cans or other aluminium products.*' (U.S. Environmental Protection Agency, 2000)

Recycled content applies where a product contains recycled material in any proportion.

For building regeneration, cyclic resource flows are defined in many ways creating complexity in the end-of-life scenarios possible. A product/element can be *Reused* in place, on site, off site and or in another application. A product can be *Recycled* to equivalent quality, downgraded quality, into a different product supply chain or *Biodegraded/composted* (i.e. recycled back into a basic resource). *Remanufacturing* can also occur, placing the product back into the same supply chain or for another supply chain. If a product is not reused/recycled/remade it is typically sent to land fill.

In addition, with the rebuilding and retrofitting, buildings, their products and materials are also made, as 'new to site' components with varying amounts of *recycled content*. Product content can be made up of *recycled or virgin* materials with potential for reuse in future, and potential for recycle-ability in future, as listed in Table 2 and Table 3.

Table 2 Cyclic resource flows

Action for product/building element	**Possible pathways**
Reuse	In place, on site, off site or another application
Recycled	To equivalent quality, downgraded quality, into another supply chain
Biodegraded/composted	To basic resource
Remanufactured	For same use, for same supply chain, or for another supply chain
Landfill	

Table 3 Recycling potential

Content of 'new' products/elements	**From where**	**Potential**
Virgin	New raw resource extracted	Reuse/recycling/landfill
Recycled	From same supply chain or other supply chain	Reuse/recycling/landfill

For the purposes of CH1 assessment, environmental impacts that are avoided (i.e. reuse credits) in recycled content and future product recycle-ability were measured in categories of:

- **Regeneration** Potential: Extant building recycle and reuse content credits (i.e. the potential for reuse/recycling of existing components) and
- **Recycle-ability** potential: Credits for existing/new components for their future recycling and reuse potential, after their current design life application.

The process assessments for CH1 are shown in Figure 3-1.

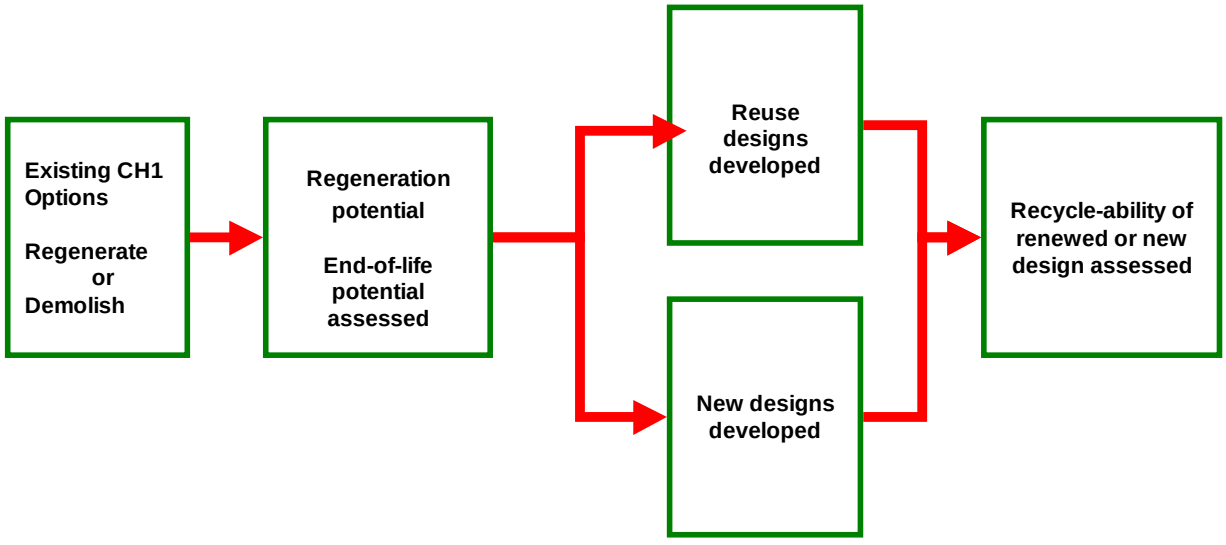


Figure 3-1 Assessments in the decision making process

The potential for the recycling and reuse of existing building components in the refurbishment are called *'Regeneration potential'* for the purposes of this report.

The potential for recycling and reuse of new building components, at the end of its refurbished life are called *Recycle-ability* for the purposes of this report.

Other useful definitions are listed in Appendix II - Definitions.

3.1.2 Regeneration potential

The regeneration potential, as in Figure 3-1, is the first assessment carried out and entails assessment of how much of a saving in environmental impacts there will be if the CH1 building is regenerated through recycling, reusing and retrofitting the building.

Recycled content or components that can be reused from here or elsewhere is measured and is generated by:

- Reusing components of the building (no treatment other than cutting to size thus contributing negligible additions to emissions),
- Reusing components as extracted from some other building or use (no treatment other than cutting to size thus contributing negligible additions to emissions),
- Reusing with minor treatment e.g. cleaning bricks (only fixed minor additional processing),
- Inclusion of recycled product in standard processing (using small percentage of existing steel in manufacturing new steel and already included in emissions), and
- Variable recycled content depending on available resource or choice of designer (needs specific proportion of recycled content for every application).

3.1.3 Recycle-ability

The ability of a building or its products to be recycled or reused depends on its ability to be deconstructed and the current supply chain systems to remove and reuse or remanufacture. Recycle-ability attempts to measure the potential of the building and its constituent products to be recycled after the regenerated building is at the end of its life.

3.2 Regeneration issues

Recycling and reuse as they relate to the regeneration of buildings is generally not fully described to stakeholders nor necessarily understood. There are numerous methods and pathways for the reuse and recycling of building components and this causes complexity in understanding, assessment and application of concepts.

There is no standard or agreed protocol for end-of-life assessment or standard methods for the construction processes for regeneration. Understanding of the recycle ability issues differs and areas of efforts differ. Proponents for inclusion of recycled content and not recycle-ability include Wayne Trusty (Wayne Trusty reference) for example.

There are many possibilities for each product and issues that go along with them. Key issues are listed and discussed below.

3.2.1 Recycling

Recycling of products as a basic concept has been the focus of current waste management opportunities in Australia (Austral in recycling reference). Extensive recycling schemes have emerged and whilst this is a positive step forward, it is not the only aspect of sustainable regeneration. Recycling is only one element of a well balanced resource management plan (often called a waste management plan).Resource management should address whole-of-life resource issues and not just what can be recycled.

Recycling should be a means of achieving a more sustainable outcome, not an outcome in itself. Recycling may not always be the most environmentally friendly option. Recycled

content and recycle-ability potential should be developed and evaluated in LCADesign in a manner consistent with a qualitative understanding of whole-of-life issues, as well as quantitative assessment.

3.2.2 Recycled content

Most building assessment tools use the term recycled content as the one measure of end-of-life potential. This term is overused, its significance over-stated and its power to reduce environmental impacts is misrepresented (PPD reference). Recycle and reuse potential is the other aspect that works with recycled content in products. Recycled content when used on its own can be more usefully applied to short turnaround applications such as packaging (Packaging recycling reference). Currently products containing recycled content (both pre- and post-consumer waste) and products which are reusable or recyclable at the end of a building's life, are considered to be more 'environmentally friendly' or 'greener' than other products. They have been advocated as a means of, for example of:

- reducing waste,
- promoting efficient use of resources, and
- providing a market for waste materials.

Using by-products of another industry or taking waste out of the waste stream, rather than using virgin materials can be good both environmentally and economically, especially if waste product is the same as the virgin material.

However, issues of recycled content and recycle-ability are not clear-cut. Recycled content of a product is not necessarily a fair representation of environmental impact and is also not feasible in some products: Simply specifying that building products should contain a percentage of recycled content would not necessarily produce environmental benefits.

Production processes, for example, can be more environmentally harmful when utilising recycled materials as opposed to virgin materials. Similarly, the quality of a product required may dictate virgin materials (such as for plate glass) even though glass as an industry has a good recycling rate and recycles into other products (Glass recycling reference). It is important to understand the supply chain that the resource/product comes from and how the product fits into it.

Some products require virgin materials: i.e. high quality float glass (which is important in the operation of buildings, for example, for natural day lighting) may have low recycled content but the glass industry has high recycling of glass into bottles, for example. Similarly, marine environment cement has high recycled content where it works and provides highest Return on Investment (ROI), and low recycled content in other cements.

It can also be difficult to determine actual recycled content amount. Recycled content may counter recycle-ability potential or vice-versa initially. Technology, innovation and marketing restrictions from forced recycled content has the potential for reduction of flexibility and creativity.

There may be no access to recycled materials: Some manufacturers may meet Recycled content targets by importing waste materials from overseas imports. Some of the highest recycled contents flows make products that are thrown away on a weekly basis and may encourage waste of resources.

Giving credits for recycled content can be in direct contradiction to other impacts, i.e. more lengthy transport than for virgin materials. LEED for example has many credit contradictions, especially in the recycling areas. It is pointless to provide recycled content data that unfairly reflects industry practice when other environmental criteria are being met. LCADesign has the capacity to overcome this problem by looking at the whole of life issues.

A Steel building product example of recycled content

> 100% Recycled Content: Product demand can seldom be satisfied solely by recycling, for example in steel supply.In the Steel industry high recycled content

is maximised in Electric Arc furnace (EAF) processes for reinforcement bar and rods because supply chain routing works. However, rails with recycled content are limited because the manufacturing route is virgin steel. Much imported steel is EAF with maximum recycled content but this has much higher CO_2 than virgin steel because blast furnaces (BF) more efficiently use coal as direct fuel (melting the iron mix) while the EAF uses indirect fuel via electricity (power stations burning coal to make steam to turn the turbine to make the powered to send over the grid (loosing 60% as waste heat in the process) (Recycled steel reference)

Therefore when deciding whether to re-use or specify with recycled or virgin content, reuse is the best option. The optimum is a mix depending on what consumers send back into the supply chain for re-use and reprocessing.

3.2.3 Services and supply chain supporting regeneration

Reuse and recycling on and from building sites in Australia is not yet standard practice. Companies that recycle/reuse/remanufacture have emerged in the last decade but they are not commonly specified as standard practice as yet. Added to this, in many cases there are still no safe methods for recycling or even disposing of materials that come off site (Australian building recycling practice reference).

It is important to source and ensure there are infrastructure/services for reuse/recycling of products. Even more importantly it is important to be able to access the demolition and construction skills required for the regeneration activities.

Disassembly also has varying levels of difficulty associated which also need to be considered when planning a regeneration project (McDonough et al, 2003).

Manufacturing techniques and recycling schemes are not in general use, i.e. may not have the means for using recycled content or means to safely recycle/ reuse. Additional transportation or processing may be required which counter benefits of recycling and may make it cost prohibitive.

3.2.4 Factors influencing regeneration versus redevelopment decisions

In order to make considered and relevant decisions developers need to be able to assess regeneration opportunities against redevelopment criteria in terms of TBL implications. Factors which affect the quantitative end result need to be determined in order to further develop Building Environmental Assessment (BEA) tools, such as LCADesign, so best options can be determined. Those factors with the most significant effect need to be determined, and international examples can be looked to for direction. Parameters which may require further investigation in subsequent Regenerating Construction Projects, based on a brief overview of BRE's Sustainable Refurbishment, include:

- Heating/ Cooling/ Ventilation Systems: providing comfort efficiently is a key decision in whether a building can be regenerated i.e. energy use and the consequent environmental impacts associated with air conditioning/ ventilation can be significant.
- Lighting: The provision of day light may make significant difference to energy consumption over a building life. Cost of artificial lighting contributes to overall operation costs of running building as well as environmental impact.
- Building orientation, size and shape, glazing area and other potential factors in heat loading: Heat gain can be considerable from factors inherent to a regenerated building.
- Embodied Impacts: Embodied impacts of construction, materials can be saved through regeneration and/ or recycling of materials. Recycle-ability potential at end of building life is also significant.
- Capital and Whole Life Costs - The major saving of a regenerated building over a redeveloped one is in the cost of the foundations, frame and structure. Whole life costs for a new build will be higher than for a regenerated building as the capital cost needs to be factored in.

- Buildability, speed and ease of construction and disruption: These factors can be difficult to assess between regeneration versus redevelopment and design and other factors are required.
- Insulation levels;
- Construction type and flexibility of change;
- Technology and infrastructure; and
- Required office space available.

Of more particular interest to developers may be those parameters which directly relate to the economics of the project such as the rental values, let-ability and manageability with each development option. Economics is the main driving factor in decision of regeneration versus redevelopment and market data from property agents, surveyors, design teams, facilities managers etc. is required. Some of the relative issues may include:

- Usability of space more important than arrangement/ floor size
- Flexibility of space,
- Accessibility for IT provisions despite moving towards wireless technology,
- Floor to ceiling heights,
- Building location,
- Daylighting provision (which developers may not recognise as an economic consequence),
- Floor loadings,
- General building appearance,
- Rent values and payback vs long term leases,
- Parking/ public transport links,
- Planning consent risks,
- Planning changes since original building making regeneration more profitable,
- Perception of new systems of heating and cooling may be a risk, and
- Investment fund considering environmental impact.

Environmental issues, including recycled content, are only a few among a wide range of issues.

3.3 Decisions for regeneration

There are at least three levels of decisions that need to be attended to ensure a consistent and relevant end-of-life program for a building.

3.3.1 Macro decisions

Higher-level decisions include whether to Reuse / Recycling or demolish a building;

- Building can be reused as whole and updated,
- Majority of structure and elements reused,
- Only major structural elements/ façade/ etc. retained, and
- What are the priorities.

3.3.2 Product/elemental decisions

These decisions are required to make the Macro decision:

- Reuse/ Recyclability of materials,
- If the material goes to landfill awareness of its fate is required such as whether a material will be incinerated for energy recovery,
- What is the best possible path for that product resource?,
- Recycled content as percentage and whether post or pre consumer waste,
- The renewable content at the end of a product's life, and
- Recyclability potential of materials i.e. Ease of Disassembly.

3.3.3 Services and support for regeneration

Services for the recycling must also exist to support the action of disassembly and cycling back resources into the supply chain:

- Infrastructure/services for reuse/recycle products,
- Infrastructure/services for construction/demolition activities required, and
- Can Disassembly occur using common tools (hammer, pliers etc.).

3.4 Life Cycle Assessment, LCADesign and Regeneration

LCADesign is based upon the international standard method of Life Cycle Assessment or LCA. LCA has both positive and negative aspects in relation to recycling of product and the regeneration of building. On the positive side Life Cycle assessment recognises the end-of-life and renewal issues in its whole-of-life assessment focus. Currently though, LCA on an international basis has a long way to go in its understanding and research on end of life issues. LEED (LEED reference) discusses the problems with LCA in relation to reuse and recycling, which in summary are:

- the complexity of LCA models does not adequately support attempts to record entire industry sectors or supply chains (which reuse and recycling require),
- the specific intent of LCA in traditional analysis does not consider or prioritize from a wide enough spectrum of concerns/issues,
- due to the complexity of the assessment priorities can be confused, e.g. Credits in for aspects of regeneration, e.g. recycled content, can often be in contradiction to each other, e.g. recycled content materials may be preferred over a locally produced material and the recycled one may have greater climatic impact. Local virgin materials may also be given preference when the recycled option is a lesser impact. Thus it is important to clarify specific project priorities

LEED does discuss that any credits will eventually lead to market transformation e.g. decentralised recycling operations and go on to say that

> *"At this stage of market development and LCA data quality, however, it is likely that few LEED credits could establish an unambiguous overall environmental benefit through the type of quantified multi-category impact analysis proposed here."*

The Journal of Sustainable Product Design (April: 20-26, ???) identified limitations with LCA that are especially relevant to recycling issues, including that LCAs are "fairly cumbersome" in tackling recycling issues. LCAs are a static, rather than dynamic analytic tool, therefore "taking the future into account is problematic, particularly for resources use."

LEED suggests that it is essential to focus specific priorities/intents on each project to focus and ensure assessment of recycling is undertaken according to the projects values. The methods of this report are aimed at CH1 in this way.

A useful review of applications of LCA in Eco-Design is Stevels, Brezet, and Rombouts (1999).

LCA results are not value free as it has to be determined how these issues can be included now and in the future and we need to be able to refine and enhance methodologies by:

- pinpointing future issues which may require consideration, and
- building in flexibility while retaining systemic integrity and practical ability.

While one aim is to reduce the environmental impact of CH1, more specific goals, however, may counter the necessity for inclusion of recycle-ability issues. For example, if reduced transportation impacts were required, recycle-ability potential may not be very important given the extra transportation required. Reducing extraction impacts however, would provide cause for specifying recycled content.

3.5 CH1 limitations and issues

Issues that may relate to the 'Regeneration versus Redevelopment' decision making process need to be further investigated.

It has been recognised that for LCADesign to consistently facilitate decision-making on sustainability initiatives, over the building life cycle, it had to feed both forward and backward from design to phases of definition, detailing, delivery and deconstruction, e.g. Sarja (), Watson et al () and Watson, Jones et al () and Mitchell () have all asserted the need for holistic life cycle structures as the basis for sustainable built environment decision-making. This is a fundamental starting point for discussion and development of BEA tools.

3.5.1 Regeneration versus redevelopment premise tested

The premise for the Regenerating Construction Project is that refurbished/ recycled buildings provide greater ESD benefits than 'demolish and rebuild' options. In future Regenerating Construction Stages this premise needs to be more rigorously tested in terms of whole building life, including the assessment of social/cultural, sustainability and economic benefits. This Triple Bottom Line (TBL) performance assessment needs to be applied to both Regeneration and Redevelopment options in order to determine which option provides greatest whole-life sustainability benefits.

4 LCADESIGN ASSESSMENT

4.1 Building models for assessment

The supplied 3D CAD model of the existing building (B1) were assessed using LCADesign which may require some modifications to match the materials in the existing building at the required level of detail. The tasks included:

- Refinement of the 3D model as required,
- Extension of the Life Cycle Inventory database as required,
- Creation of additional reasoning rules, and
- Analysis of the results.

The assessment of the refurbishment design (B2) by LCADesign was not undertaken although some additional features were incorporated in the assessment procedure as well as the modified 3D CAD model. The planned tasks included:

- Refinement of the 3D model as required,
- Improvements to LCADesign to incorporate measures of refurbishment (i.e. the parts of the building which can changed in the refurbishment design compared to those components which remain static from the first 3D CAD model),
- Extension of the Life Cycle Inventory database as required for any new materials/components,
- Creation of any additional reasoning rules if necessary for refurbishment activities, and
- Analysis of the results.

Due to the lack of a refurbished building, no 3D CAD model could be created. However, the facilities for identifying recycled content and retained components were implemented in the updated LCADesign. Only the recycled content facility is fully operational.

4.2 Additional development of LCADesign

Significant effort was applied to LCADesign improvements to satisfy both the needs of the existing building and the potential refurbished building.

Key development activities undertaken in the LCADesign software are outlined below:

- LCI database,
- Reasoning Rules,
- Tagging in 3D CAD,
- Interface and analysis tools, and
- Modelling in 3D CAD.

The Life Cycle Inventory (LCI) database is currently at prototype stage and, whilst intending to include end-of-life issues was as fully implemented as possible for the refurbished building, e.g. provision for recycled content in the database and in the assessment calculations is operational. The database still needs to deal more fully with all end-of-life issues covering reuse, refurbishment and waste processes.

The Product Reasoning Rules (PRRs) and Object Reasoning Rules (ORRs) in LCADesign allow materials/unit processes or products to be combined into specific building products. Additional PRRs and ORRs are required in order to correctly model the existing building and

cater for the materials involved in reuse, refurbishment or demolition choices in the refurbishment project.

Tagging is a key step to identifying products for the LCADesign assessment and required minor changes from the user perspective, e.g. choosing the Reasoning Rule that specifies whether the element is to be new, reused or demolished. The modifications to LCADesign to achieve this was determined and a mechanism for achieving the appropriate tagging designed but not implemented when it became obvious that the 3D CAD model of a refurbished building was not going to eventuate as the procedures could not be applied to a practical example.

The Reasoning Rule Manager was significantly enhanced during this project by:

- Adding the capability for the user to select any database as well as the default database,
- Adding the entering of the lifetime of a product,
- Adding the recycled content of a product,
- Reformatting the printed file of the Reasoning Rules to improve readability, and
- Making the Reasoning Rule Manager much more user friendly.

The LCADesign software also underwent substantial improvement by:

- Adding the capability for the user to select any database as well as the default database,
- Adding substantially more information to the error reporting, such as:
  - Identifying Object Reasoning Rules used in tagging a 3D CAD model and not existing in the database (resulting from tagging with the incorrect Element Codes file), and
  - Identifying Object and Product Reasoning Rules which did not have the required dimensional data in the IFC file (most commonly resulting from limitations in the IFC file not transferring a value for non-rectangular objects),
- Adding Mass and Recycled Mass to the list of indicators available,
- Adding the impact of replacement items during the lifetime of the building to the total outputs by estimating how many times the object would be replaced during the expected life of the building (The lifetime of an object was taken as the shortest lifetime of those products in an Object Reasoning rule with rules to ensure that replacements near the end of the life of a building do not occur in the last ten per cent of an lifetime of an object.),
- Revising the interface and analysis tools to present the available additional end-of-life impacts to the user in a useful way.

4.3 Life Cycle inventory

The product inventory called the LCI database contains resource consumption and emissions generation data in a hierarchy of industrial processes and “intermediates” with an ability to compile these attributes into an inventory at any node in the hierarchy based upon unit mass factors. Product attributes such as density are needed to convert unit operations to that of equivalent functional units used in the 3D CAD model.

The LCADesign inventory consists of all processes in acquiring, processing, and delivering various qualities of products for building construction, e.g. concrete products such as cement for mortar, cement sheet 4.5mm, concrete-20Mpa, concrete masonry 200mm, precast concrete and cement render. Several well known models exist for various industry sector processes in various countries; a typical European model of emissions is the Boustead Model (Boustead, 1995), developed in England over forty years, for identifying and logging unit operations for all processes contributing to building product manufacture. The inventory

of all energy, fuel, raw material and emissions so generated is calculated, compiled and transposed to the product database.

The Boustead Model contains such data for various products via models of manufacturing operations involved, from raw material acquisition, manufacturing, use and disposal. Details of direct and indirect feeds into all operations are accounted for contribution to the complex process web that comprises any particular product. All emissions data in each process web is aggregated for the entire process flow to derive gross totals for any product.

As part of this project, the Boustead model was updated to representative Australian products used in construction of the Council House 1 building along with estimates of the use of recycled materials during the manufacture of these products. The result was a new but limited LCI database specifically targeted towards the products used in the Council House 1Building and its proposed refurbishment. Thus, in addition to the standard construction products, alternative products which potentially have a lower environmental impact (including use of recycled material) were identified and added to the LCI database. The additional products with lower environmental product provide the opportunity to compare the impacts of using of alternative products.

4.4 Calculation of recycled content from LCI data

By definition, a Life Cycle Inventory (LCI) undertaken by following the method defined by the ISO 14040 suite of standards will capture the resources and emissions of the whole life cycle of a process, within a stated boundary. Hence, if the inputs to a building element process contain recycled material then the outputs from that process will include the benefits (or burdens) compared to a similar process that does not include recycled material. Consequently a whole building life cycle assessment based on such LCI data will include the benefits (or burdens) embodied in its building elements.

However, the proportion of recycled content incorporated into the design could be considered as an indicator of eco-efficient performance and is indeed used in some systems of measurement of eco-efficiency performance.

It is conceptually possible to calculate a measure of recycled content of a building product directly from the Life Cycle Inventory (LCI) data for the product. For the purposes of this discussion the definition of “recycled content” is the percentage (by mass) of non-virgin, recycled or reused material incorporated into the manufacture of the building product.

The reuse of existing building elements, either “in-place” or elsewhere on site, is considered to be separate from the amount of recycled material incorporated into “new” building elements. Depending on the context or definition of “recycled content” the reused elements may also contribute to this measure.

Each building product is defined in the LCI data as a “process”. Each process is made up of a table of inputs, each input being an amount of another process. Therefore each building product can be thought of as an inverted “tree” of processes that end in amounts of emissions and resources at the “leaf” nodes. If, for example, the amount of cement is required from a unit quantity of ready-mixed concrete then it is a simple matter to follow the “tree” of input processes for ready-mixed concrete down to the cement process and read it’s amount.

This method could also be used for “virtual” unit processes and has already been demonstrated for the calculation of budget costs. A “budget cost” process with the quantity of $1.00 was created (unit process number 90001) and then each building product’s Product Reasoning Rule (PRR) included an appropriate amount of this cost process to give the budget cost for a unit of the building product. This was done in the reasoning rules and not in the LCI data because the budget costs only applied to the final building products. In the case of recycled content it is necessary to add information to the LCI data because recycled content applies to processes at a lower level. For example, 80% recycled reinforcing steel should include a “recycled content input process” with a value of 0.8.Then this reinforcing steel process will be used as an input process to a composite building product and the

recycled content measure can be calculated by the relative proportion of reinforcement within the composite building product.

Building products are not normally measured by mass. Usually building products are measured by length, area or volume and therefore a density figure (kg per process unit) is also required in order to calculate a proportional measure by mass. Currently each PRR defines a formula to make any necessary conversions between the unit of the LCI process (usually in kg) and the unit required by the ORR (e.g. metre or square metre).

Qualitative measures of “Recycle-ability”, “Deconstruction potential”, “Made in Australia” and others could also be provided with virtual unit processes. In these cases the amount of a virtual unit process will be irrelevant and just its presence in the input table provides enough information. These types of virtual unit processes could also be used to inform LCADesign users who want to target products with certain characteristics, e.g. “Show me product alternatives that are recyclable”.

Default logic needs to be carefully applied in order to minimise the work required in the LCI data. For example, if a process does not contain the “recycled content” process anywhere in its expanded input table (i.e. including its input’s input tables) then it must be assumed that it does not contain any recycled content.

The disadvantage of this method is the extra work required to add information to the LCI data. However, this information must be entered somewhere in the system and it is the LCI professionals who will have the best knowledge and capability to capture density and recycled content information. It is also best practice to keep all this information together as it applies to the unit process.

The calculations belong in the Inventory rather than in LCADesign. Currently this information could be entered using the Boustead software to edit each LCI unit process. This is a time consuming task and alternatives was considered and implemented. The RRManager of LCADesign was modified to show and modify unit process at the PRR level. This approach also aids in checking and verifying the values of recycled content. The value of recycled content was garnered from LCI databases and known practices.

The advantage is that the recycled content quantities automatically filters up the input processes tree and is available to LCADesign for calculating measures of recycled content and total mass of designs. This approach could also cater for many other quantitative and qualitative measures to be reported.

4.5 Recycled content in the Life Cycle Inventory database

Most of the recycled components are identified in the Reasoning Rules but there are additions from the Boustead model. If the product is a specific recycled product line, e.g. reinforcement bars which can be made at a different steel manufacturer that includes a certain percent of recycled steel, these different product lines are distinguished from each other.

A measure for recycled content was provided as a “stressor” in the LCI database to represent a percentage of recycled content. It is assumed that recycled content is a percentage of total mass. For example, if a steel beam was made of steel with 80% recycled content then an LCI product would need to be created which uses 0.8 of the “Recycled content” process. It is also assumed that any product that does not use a quantity of the “Recycled content” process is 100% virgin product.

The recycled measure is calculated by keeping track of the total mass and recycled mass of each building element and dividing these totals to get the overall proportion of recycled material. Such a measure is not able to make any quantitative statement about the value of the recycled content, just how much recycled content there is. This may not be such a great problem because by using recycled content the designer has already reduced many impacts due to minimisation of virgin material.

A refinement may be to use material specific “Recycled content” processes in the LCI such as “Recycled steel”, “Recycled aluminium”, “Recycled glass”, “Recycled timber”, etc and then

report on them separately at the stressor level in the same way that the current measure of “Embodied water” can be reported as “Sea water”, “Public supply”, “Well”, etc. This may be difficult to calculate for composite elements, so further thought is required here.

Any level of recycled content can be catered for in the reasoning rules by applying different amounts of 100% virgin and 100% recycled material into an object reasoning rule. This requires the usual amount of expert knowledge to create and use object reasoning rules that are both realistic and comprehensive.

4.6 LCADesign software outputs

Additional choices of chart type in the analysis summary tab were added to LCADesign to show recycled mass and total mass. The fate of removed objects is not being dealt with here.

Recycled content initially is considered as just another measure and included on charts as mass or proportions of whole building just as any measure is currently considered. The advantage of this approach is that the existing capabilities to drill down by element classification are available. Essentially, this approach requires only adding recycled content categories to the choice of X axis eco measures.

An existing building and a refurbished building are treated as two separate designs with comparisons made in LCADesign analysis. Both designs would need to have same set of objects tagged as reuse on site.

Recycled content and recycle-ability potential (not implemented) as discussed in the outputs section needed to be identified, presented and provided with a drill down according to the reuse/recycle/landfill etc categories.

The existing building was modelled as per the LCADesign 3D CAD model guidelines. To account for the processes of removal of wasted building elements it was necessary to model these as well. Potentially the design model contains the final building elements as well as the “ghosts” of the existing building. (A “greenfield” building does not need this obviously.)

4.7 Reasoning rules for refurbishment

The new reasoning rules for refurbishment were based around the principles of:

- There would be no changes to the Tagger in ArchiCAD other than the ability to have multiple tags,
- Recycled content and recycle-ability were included as additional items in the Product Reasoning Rules, and
- Fractional (or multiple) rules were included in the Object Reasoning Rules to allow for proportions of different Product Reasoning Rules within the object with the additional capability to define the number of occurrences of a PRR (e.g. only one rule is required for a coat of paint as the number of coats can be identified in the ORR, thus reducing the number of PRRs required).

This allows for great flexibility in defining recycled content, recycle-ability potential and multiple rules applying to the on object. The changes mean that extra care is required when tagging and making up Object and Product Reasoning Rues.

4.7.1 Object Reasoning Rules

To implement the identification of retained materials requires a change is in the naming of the Object Reasoning Rules. All the rules would begin with one of the following words followed by a dash (-):

- New
- Retain
- Demolish

New is the same as currently used.

Retain indicates that the object will be retained in a refurbished building and commonly would be the same as *New* except where Retain included additional rework such a new finish.

Demolish would normally be the same as *New* with additional Product Reasoning Rules for removal operations.

Use of the key leading words enables the materials used to have an additional category for analysis, particularly to identify how much was retained and extra effort for removal. Thus all existing Object Reasoning Rules used in CH1 would have to be renamed and additional Object Reasoning Rules created by replicating the existing rules, slightly modifying them and giving them a new leading word. Identification of the new category occurs when the Object Reasoning Rules are being interpreted in LCADesign.

LCADesign can process multiple rules for the same object – the previous version of the addin for ArchiCAD 8.1 only allowed one rule per object.

The definition of the Object Reasoning Rule (done in the Reasoning Rule Manager) now requires an additional multiplying factor for each Product Reasoning Rule. If the factor is blank, it is assumed to be 1. Use of integer values e.g. 2 or 3 replaces identical repeated Product Reasoning Rules and slightly reduces calculations. Fractional factors are used where part of the object (e.g. 0.25 or 25%) is one product and the remainder (0.75 or 75%) is another, in which case, the sum of the factors must be equal to 1. The object could have been modelled as 2 objects but there are many instances of objects not being split because they look similar.

Use of more than one Object Reasoning Rule tagged to a single drawing object allows for the Object Reasoning Rules to have a non-finish (mostly structural) rule and a finish rule (where these have been defined separately) for each object. Variations can then be focussed on the finishes (say) without having to create a series of combinations of non-finishes and finishes.

While the system for identification of retained and demolished components of a building was designed and specified, it was not implemented as it required a change to the ArchiCAD tagger to allow multiple rules to be added to an object.

4.7.2 Product Reasoning Rules

Each Product Reasoning Rule has two additional parameters, recycled content and recycle-ability potential. Where these are blank, the vales a re assumed to be zero in the calculations. The values of the recycled content and recycle-ability potential are produced from modifications to the LCA model and hence automatically included in the LCI database when it is updated. The recycle-ability feature was provided for in the database but its application was not implemented in the RRManager or LCADesign.

4.8 Measures and charts

New categories of measures planned were

- Recycled and Not-recycled,
- New, Retained, Demolished, and Waste, and
- Recycle-ability and Non Recycle-ability

but only the first was implemented.

Two completely new charts were planned

- Any indicator value by element breakdown in a stacked bar by New, Retained and Demolished categories along the x axis.

- Any indicator value by New, Retained and Demolished breakdown in a stacked bar by indicator category along the x axis (i.e. New, Retained and Demolished replace element breakdown on earlier charts).

The charts depended on the availability of the New, Retained and Demolished breakdown and would only be available in the analysis stage. As the breakdown was not available the new charts could not be made operational despite the provision in LCADesign for the data.

4.9 Analysis

Recycled content and total mass are available during any analysis as another indicator to be selected. All the previous functions of drill-down, categories, choice of designs etc operate as previously.

New, existing and refurbished buildings must be prepared as different 3D CAD models even when the model objects are identical – the only difference may be the tags. An Object in a building model cannot simultaneously have New, Retained or Demolished status. Comparisons would be made though the Analysis function in LCADesign.

5 ANALYSIS OF EXISTING BUILDING

5.1 Setting up the database

The 3D CAD model obtained for this project was modified substantially by the addition of the internal walls. The structure including external walls was unchanged.

It was necessary to retag the 3D CAD model entirely. The process of retagging commenced with a database completely empty of Reasoning Rules. Development of the required Reasoning Rules began by making a list of Object Reasoning Rules needed to tag the 3D CAD model of Council House 1. Each Object Reasoning Rule was then developed/ expanded by listing all the component materials and creating blank Product Reasoning Rules for each of the Object Reasoning Rules and identifying the corresponding products in the Boustead LCI database. This list of LCI products became the master list in the CH1 database. Thus the database used is very specific to the Council House 1 model.

Each of the Product Reasoning Rules was then completed by adding a formula, the appropriate LCI item, expected lifetime in use and unit of measurement. The Object Reasoning Rules were then reviewed to check on multipliers (usually 1) for part or multiple uses of the base Product Reasoning Rule (such as 2 for two coats of paint or a fraction for part glazed internal walls). Recycled content of each Product Reasoning Rule was manually added in the list in the Object Reasoning Rule when the multiplier was checked. Recycled content was restricted mainly to reinforcement bars (up to 99% recycled) and fly ash concrete.

Environmentally better performing products (as judged by experience such as increased recycled content or “known green” materials) were created for almost all the Product Reasoning Rules and consequently alternative Object Reasoning Rules to tag or use in the variation system in LCADesign.

While LCADesign can calculate the retained proportions of a building or element, the capability to interpret this information in the proposed new format of the Object Reasoning Rules was not implemented.

The list of both Object and Product Reasoning Rules for the standard rules are shown in Appendix III.1 - Rules for design 'CH1 existing', while the list of Object and Product Reasoning Rules for the environmentally better performing products is shown in Appendix III.2 - Rules for design 'CH1 existing for lower impact materials’.

5.2 Demonstration analyses

Some comparisons demonstrating what might have been obtained if a refurbished building had been available can be shown using the original building and the same building constructed of environmentally better performing products.

Figure 5-1 shows the first level breakdown of Eco-indicator 99 for the standard Council House 1. The major contributors to the Eco-indicator 99 score are the upper floors (columns , slabs and beams of the structure) followed by the floor finishes (predominantly carpet), the internal walls and external walls. As is typical of buildings, the ecosystem quality measure makes a much smaller contribution than the resource consumption and the human health indicators.

When the Object Reasoning Rules (as listed in Appendix III.1 - Rules for design 'CH1 existing') were replaced with lower environmental impact rules in Appendix III.2 - Rules for design 'CH1 existing for lower impact materials’. The human health and resource consumption components declined substantially (see Figure 5-2) but the ecosystem quality score increased (from a very low level) (as a result of ??). Figure 5-3 shows a similar chart with the breakdown only for only the high levels of elements.

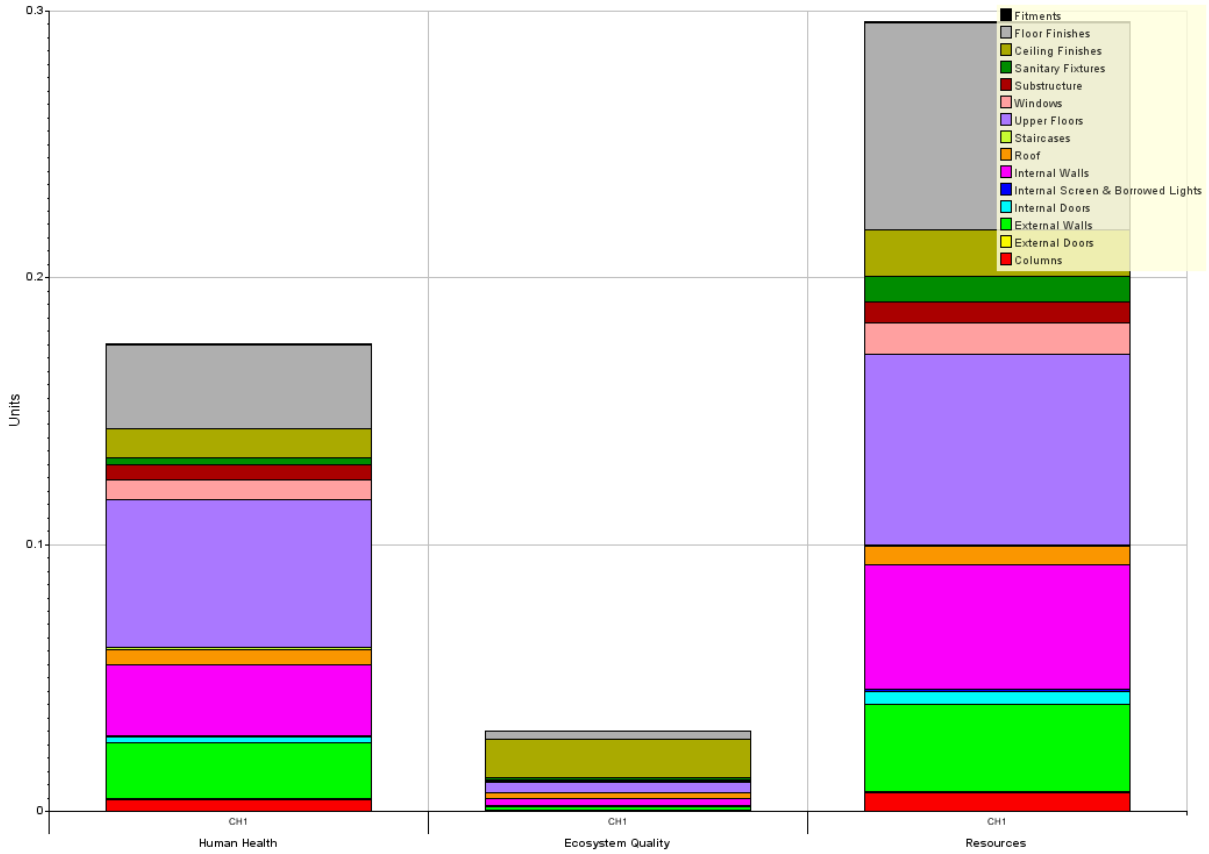


Figure 5-1 Three components of Eco- indicator 99 for the existing CH1 building

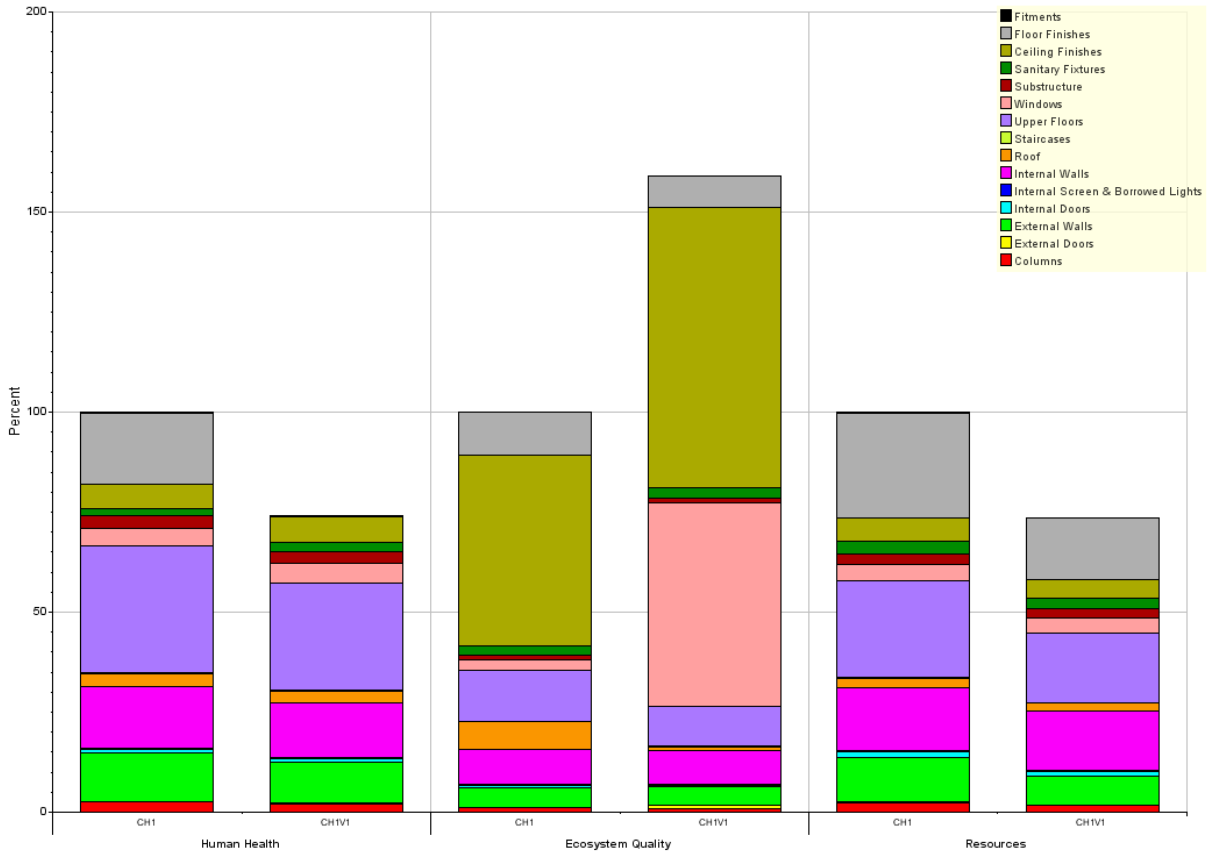


Figure 5-2 Comparison of the existing CH1 building and the same building constructed of lower environmental impact products for the three components of Eco- indicator 99

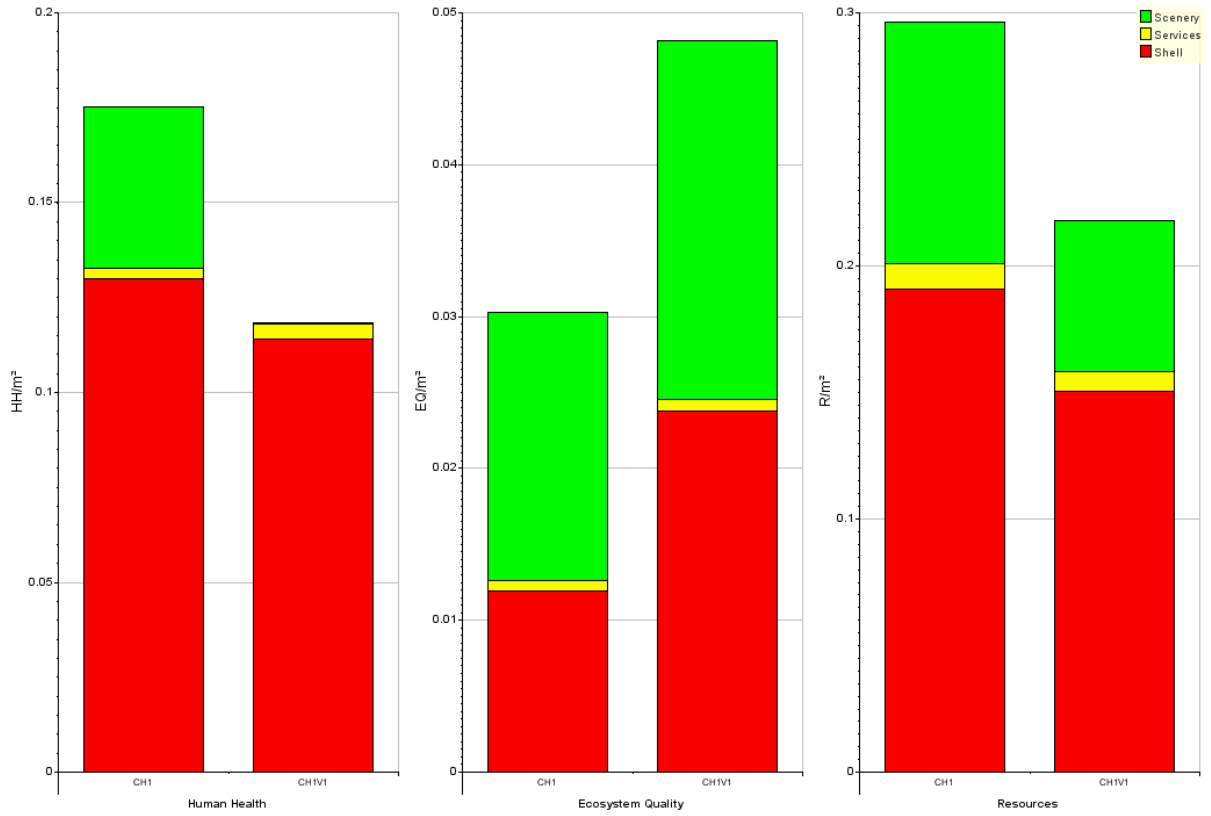


Figure 5-3 Comparison of the existing CH1 building and the same building constructed of lower environmental impact products for the three components of Eco- indicator 99 showing breakdown by high level elements

LCADesign provides a drill-down capability and the result of the same view as in Figure 5-3, but for the shell only. Figure 5-4 clearly identifies the windows as the major cause of the increase in the value for the ecosystem quality indicator. Drilling down further to the components of the internal walls shows that the major improvement is in the concrete block walls.

There are many options for choosing indicators in LCADesign. Figure 5-6 shows the values of six of the indicators for both the existing CH1 building and the same building constructed of lower environmental impact product. The six indicators are, Eco-indicator-99, embodied energy, embodied water, greenhouse gas emissions, mass and recycled mass. While the overall indicator (Eco-indicator 99) and others have decreased, the embodied energy component has risen, driven by the big increase in the scenery (fittings) component.. As expected the recycled mass has also risen sharply as a result of using 99% recycled reinforcement bars and concrete with a 7% flyash content.

A closer look at the drill down of the shell component (Figure 5-7) for four indicators shows the correlation between the increasing ruse of recycled material and reduced environmental impact as measured by Eco-indicator 99.

This small selection of a wide range of possible outputs illustrates how useful the breakdowns are in determining which components have benefited from choosing lower environment materials and which have not. The charts also demonstrate that not all indictors will decrease with increasing use of recycled content as shown by the embodied energy indicator.

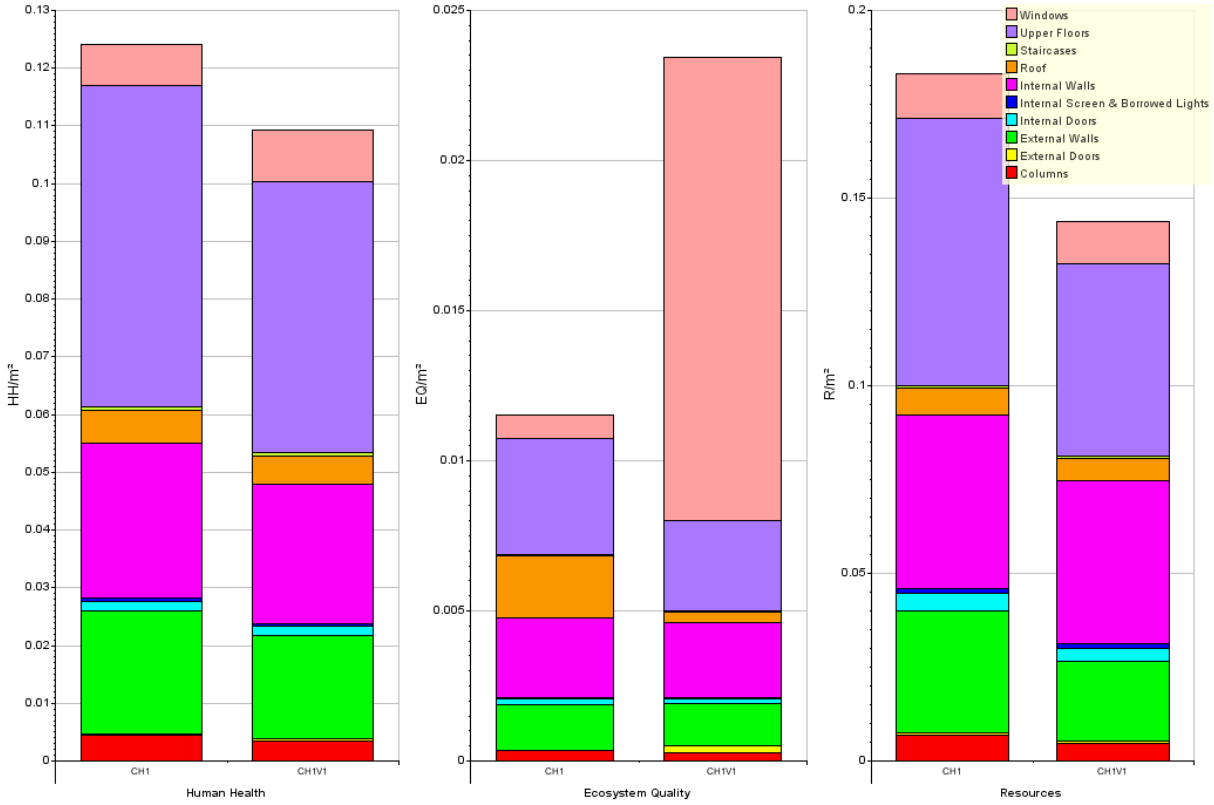


Figure 5-4 Comparison of the existing CH1 building and the same building constructed of lower environmental impact products for the three components of Eco- indicator 99 showing breakdown by elements of the shell

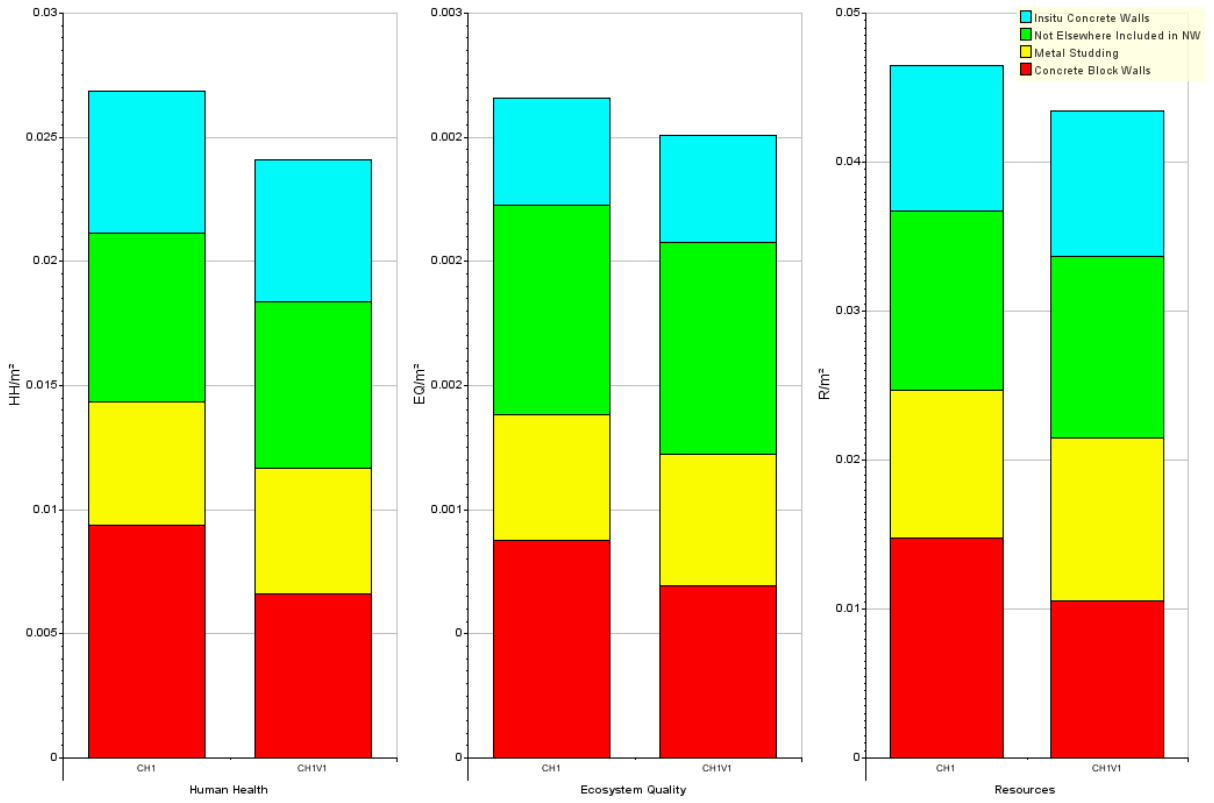


Figure 5-5 Comparison of the existing CH1 building and the same building constructed of lower environmental impact products for the three components of Eco- indicator 99 showing breakdown by elements of the internal walls

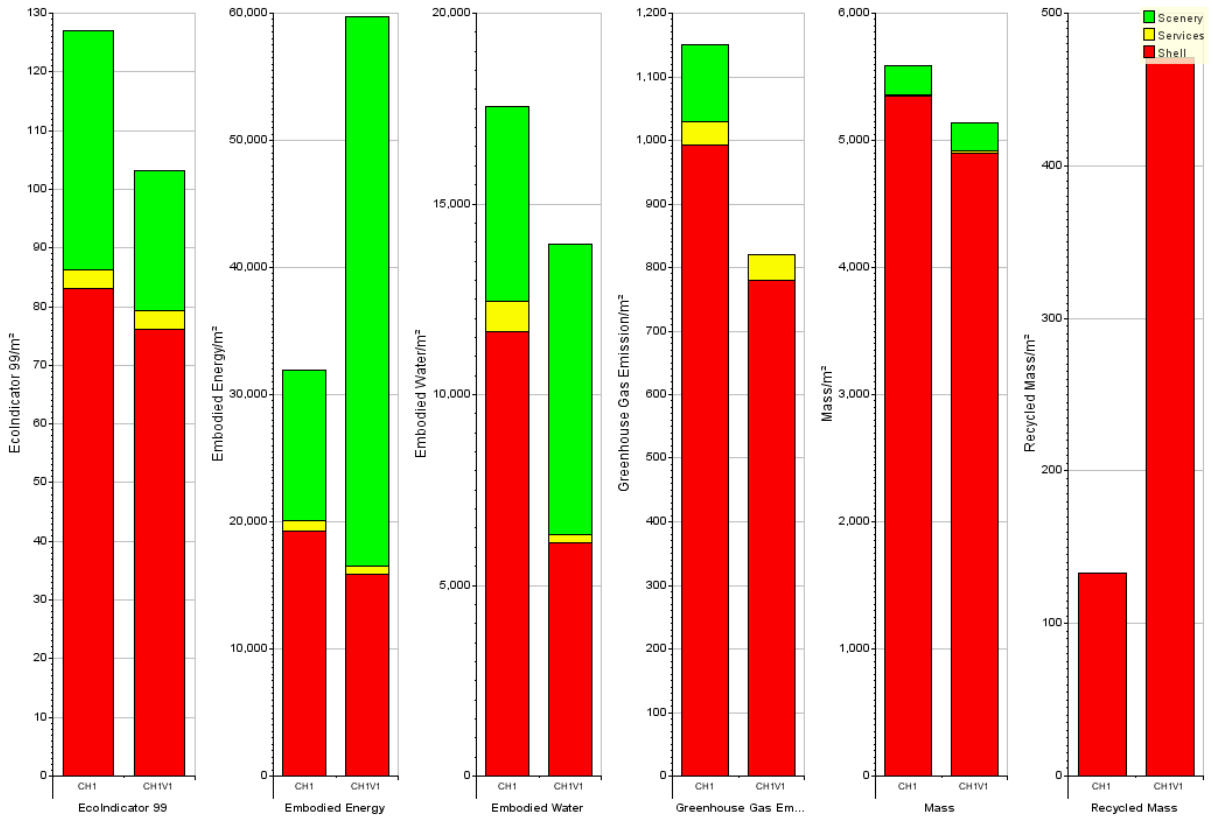


Figure 5-6 Comparison of the existing CH1 building and the same constructed of lower environmental impact products for six indicators

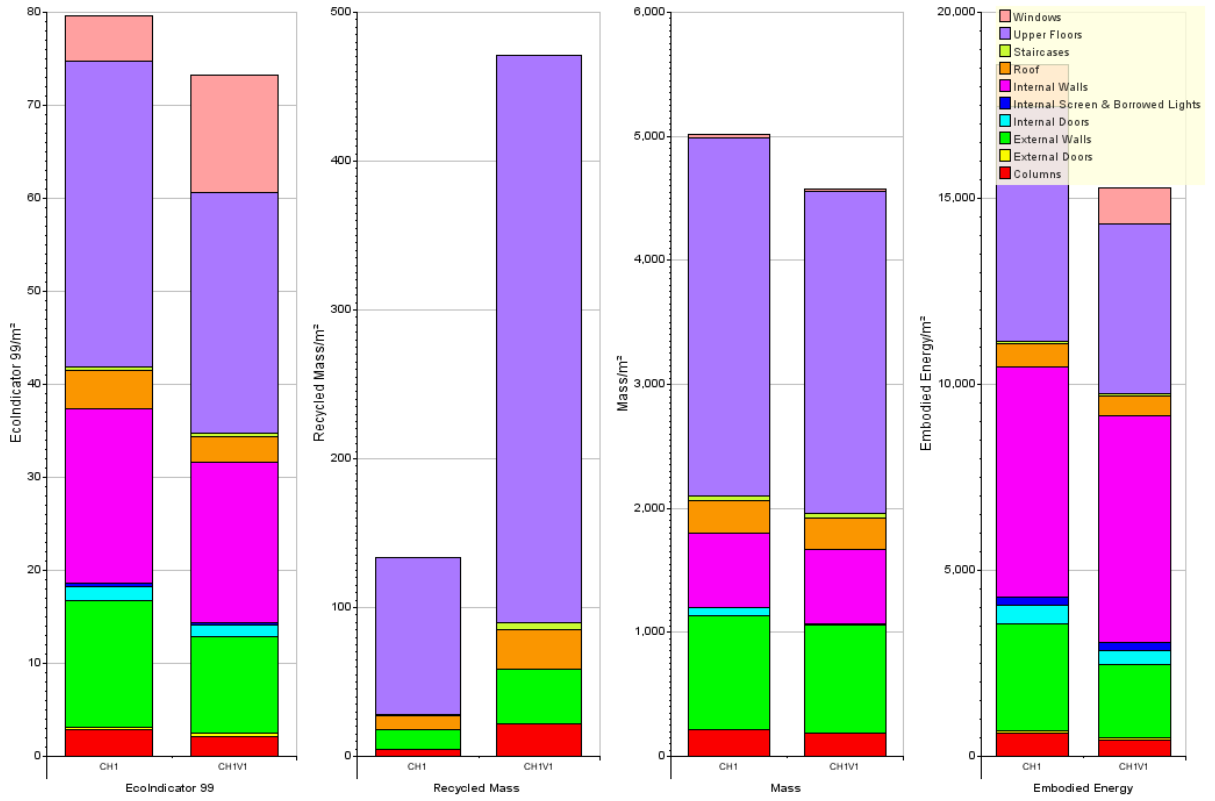


Figure 5-7 Comparison of the existing CH1 building and the same constructed of environmentally better performing products for four indicators at the shell level of breakdown

6 NABERS

6.1 Outline of NABERS

NABERS (the National Australian Built Environment Rating System) is a performance-based rating system for existing buildings. NABERS rates a home or commercial office building on the basis of its measured operational impacts on the environment. NABERS attempts to assesses the following for their impact on the environment (NABERS, 2006):

- Energy used to provide lighting, heating, cooling and ventilation,
- Water used for washing, drinking, for toilets and air conditioning,
- Waste generated,
- Quality of the air in buildings,
- Local biodiversity affected by the construction and tenancy of buildings.
- Natural storm water flows,
- Toxic materials present in buildings, and
- Travel to and from buildings.

NABERS is designed to provide building owners, managers or occupants with a simple indication of how well they are managing these environmental impacts compared with peers and neighbours.

6.2 NABERS assessment

A NABERS evaluation was done by others for the client's (Melbourne City Council's) existing Council House 1 and provided to the project. The results are shown in Figure 6-1.

As expected, Council House 1 did not perform very well but the aim was to benchmark the current performance and compare the refurbished building with the base case.

The measures used in NABERS are all focussed on the operational activities and thus complements tools such as LCADesign which focuses on the design and construction stages of a building, particularly the materials used. There are no inputs to NABERS which results from LCADesign can provide at this point in the development of LCADesign, although proposed additions for water and energy consumption would begin the process of predicting the performance of a building and thus providing some input for NABERS. A similar situation exists with GreenStar, although it does have an input for use of recycled material which LCADesign supplies directly as result of an analysis.

NABERS Commerial Office Building Assessment		
Council House, 200 Little Collins Street, Melbourne		
Overall NABERS Score:	***0/10 representing Failed performance.***	
Summary Scores		
Greenhouse Score	0.0/5	
Water Score	3.5/5	
Site Management Score	2.6/5	
Detailed Scores		
Environmental Issue	**Score**	
Energy/Greenhouse	0.0/5	
Refrigerant GWP	5.0/5	.....
Refrigerant ODP	5.0/5	.....
Water Use	4.4/5	....
Stormwater Runoff	1.2/5	.
Stormwater Pollution	0.6/5	.
Sewage Outfall	5.0/5	.....
Landscape Diversity	1.8/5	..
Toxic Materials	2.7/5	...
Indoor Air Quality	missing data/5	

Figure 6-1 Preliminary NABERS assessment scores for existing CH1 building

7 SUMMARY

7.1 General

The project was unable to compare the pre versus post refurbishment at a whole building level and relevant sub-system level for the designated Council House 1 building as the refurbishment of the building was postponed for some years. However, LCADesign was used to analyse the existing Council House 1 and set up the modifications to LCADesign for application to a refurbished building. A preliminary NABERS assessment of the existing building was undertaken and provided to this project but no GreenStar assessment was done on the existing building due to the high cost of the assessment.

It was clearly shown that an existing 3D CAD model could be easily adapted to the needs of LCADesign by adding additional objects as required.

A measure of recycled content was added to LCADesign with the required recycled content of every product used being readily added to each Product Reasoning Rule.

Among the other many improvements to LCADesign was allowing for a multiplier for the Product Reasoning Rule in the Object Reasoning Rule to improve flexibility and reduce the number of Product Reasoning Rules in each Object Reasoning Rule and number of database items and calculations required.

A methodology was developed and provision made in LCADesign for comparing the environmental impacts of the new, retained and demolished components of a building but no comparisons were made due to the lack of a refurbished building with which to compare the existing Council House 1.

A completely new database of Object and Product Reasoning Rules was created to make the products used specific to Council House 1 and to provide for alternative products which have lower environmental impact and were expected to be used in the refurbishment. The development of a specific database made it much easier to tag the 3D CAD model and provide clear alternative products. This approach should be followed up in any redeveloped version of LCADesign.

In a similar manner, the creation and/or replication of Object and Product Reasoning Rules for each new 3D CAD model made checking, running and analysis of the 3D CAD model much easier from user's point of view.

The Boustead Lie Cycle Inventory model was updated to representative Australian products used in construction of the Council House 1 building along with estimates of the use of recycled materials during the manufacture of these products. The result was a new but limited LCI database specifically targeted towards the products used in the Council House 1 Building and its proposed refurbishment. Thus, in addition to the standard construction products, alternative products which potentially have a lower environmental impact (including use of recycled material) were identified and added to the LCI database. The additional products with lower environmental product provide the opportunity to compare the impacts of using alternative products.

Recycled content can now be estimated for use in other rating schemes such as GreenStar.

An example of use of alternative building products with lower environmental impact showed that the Eco-indicator 99 score could be reduce by up to 20% (?).

Fitout (internal walls) have almost as big an environmental impact as each of the structure and the external walls

The major contributors to the Eco-indicator 99 score were the upper floors (columns, slabs and beams of the structure) followed by the floor finishes (predominantly carpet), the internal

walls and external walls. As is typical of buildings, the ecosystem quality measure makes a much smaller contribution than the resource consumption and the human health indicators.

While the overall indicator, Eco-indicator 99 (and others), decreased, the embodied energy component rose, driven by the big increase in the scenery (fittings) component. As expected the recycled mass also rose sharply as a result of using 99% recycled reinforcement bars and concrete with a 7% flyash content.

There appears to be a correlation between the increasing ruse of recycled material and reduced environmental impact as measured by Eco-indicator 99.

The use of 3D CAD models provide an excellent starting point for application of Life Cycle Analysis to buildings and LCADesign has the potential to be a unique tool for analysis of buildings at the design stage for both new buildings and refurbished buildings. The extension to refurbished buildings fitted very well within the framework previously developed for new buildings.

The major impediment to the use of LCADesign, or any other assessment tool, is the lack of reliable, consistent data for the various building types and for the major locations in Australia. Gathering better data is a requirement before “design for disassembly” can become a mainstream design consideration when selecting materials and components.

7.2 Software

As a result of the use of LCADesign on Council House 1, a number of suggestions for improving LCADesign were identified, in addition to those which were necessary to undertake the analyses required for this project, as listed below:

- The ArchiCAD addin (or proposed viewer tagging) should allow for tagging multiple Object Reasoning Rules to each object.
- The ArchiCAD addin (or proposed viewer tagging) should provide for an additional attribute for each object tag for identifying whether the object is new, retained or demolished.
- The Reasoning Rule Manager should be integrated with LCADesign.
- The data on recycled content should be in the LCI database and derived directly from the LCI model not added via the Reasoning Rule Manager.
- There should be a facility to import Reasoning Rules into one database from another database.
- Calculating and display of the proportions of the building which are new, retained or demolished should be completed.

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Appendix I - Outline of project

I.1 Overview of whole project

I.1.1 Background

The focus of development in the built environment is moving from “demolish and rebuild” to refurbishment as increasing acknowledgement is made of the social, cultural and economic benefits of refurbishing appropriate existing buildings rather than bulldozing them. The goals of such refurbishment projects are a range of Environmentally Sustainable Development (ESD) benefits compared to the performance of the existing buildings. These include energy, water, waste, indoor environment (health and productivity of occupants). Regenerating Construction to Enhance Sustainability is a Construction Innovation project designed to assist in the delivery of superior refurbished buildings according to a core set of sustainability criteria. These are:

- Eco-efficiency: minimising the ecological footprint of the refurbished building (compared to predecessor) within an agreed budget
- High quality indoor environment: where the refurbished building has achieved demonstrable improvement in respect of key IEQ criteria, including thermal performance and indoor air quality
- Healthier and more productive working environment: as measured by performance of occupants pre vs post refurbishment
- Waste minimisation: The AEC-FM industry contributes a significant proportion of the waste that goes into Australian land fill sites. The major peaks in waste generation occur in two distinct phases of the building life cycle - initial construction and refurbishment/demolition. This task will examine how to reduce the generation of waste during construction, ie off-cuts, over ordering, etc, and refurbishment, by increasing recycling and re-use. Dual objectives relate to minimisation of construction waste during refurbishment [refer to proposed R & D in Program C] and minimisation of waste generation during next refurbishment (or demolition) phase as a result of designing for dis-assembly during the current refurbishment [proposed R & D in Program B].

These are all quantifiable elements, the results of which could be employed to estimate the contribution to improved TBL performance of the entire built environment that could be achieved via refurbishment of existing stock to prescribed levels.

I.1.2 Business basis

A more sustainable built environment will be created via an improved process of refurbishing existing building stock. In order to achieve this objective, Construction Innovation needs to undertake a project where sustainability principles and targets are implemented in typical office refurbishments in order to quantify the Triple Bottom Line (TBL) benefits (building life cycle cost, lifetime environmental performances and occupant performance) that can flow from new Research & Development knowledge. Benefits will accrue not only to the built environment, but also to Architectural, Engineering and Construction (AEC) industry via dissemination of improved (re)design, procurement, construction and management processes via superior performance of refurbished building.

I.1.3 Project statement

This project is designed to assist in the delivery of demonstrably superior green buildings in respect of:

- Eco-efficient re-design: achieving a smaller ecological footprint and within budget

- Enhanced indoor environment quality and performance, reflected in improved health, well being and productivity of building occupants
- Waste minimisation (through re-design for dis-assembly and construction waste reduction).

The target buildings will cover several selected smaller projects, or a single large project if one can be identified within the appropriate timeframe. Negotiations are underway with several potential client organisations.

This will be achieved by a program of R & D that will examine a range of available projects and will focus on 4 key TASKS:

1. Use of LCADesign Green Star and NABERS as assessment tools for building redesign (original vs refurbished building). It will assist industry with respect to benchmarking practice and harmonisation of current Australian assessment tools – and is in line with CRC's role in the Green Space activity (now the Australian Sustainable Built Environment Council, ASBEC)).
2. Developing design guidelines for delivering high quality indoor environments (an industry benefit as well as one tailored via Charette to client requirements) and protocols for their measurement.
3. A before vs after survey of building occupant health (where a project is identified early enough in the refurbishment cycle), well-being and productivity, in order to value the benefit of enhanced indoor environments to the building owner and more broadly to industry (see research methodology section).Task 2 and 3 need to be undertaken on the same refurbished building.
4. A prototype tool developed for use in association with 3D CAD that can assess material selection on the basis of ease of dis-assembly, re-use and recycling (thereby minimising waste generation in subsequent refurbishment or demolition [a beta version only for this specific refurbishment application. If received positively by industry it can be developed as an additional module for LCADesign].

I.2 Task 1

I.2.1 Research methodology, objectives, strategies

The project objectives outlined above will be addressed as follows:

Eco-Efficiency Assessment of Building Refurbishment

Three “green” building tools currently exist in Australia with a capacity to undertake before vs after refurbishment assessment to varying levels of quantification:

Tools to Advance Sustainability through the Building Lifecycle

Intended Users & Beneficiaries	Intended Phase of Application				
	Strategic Planning & Schematic Design	Detailed Design & Specification	Construction & completion	Operation, including Repairs & Maintenance	Refurbish & Refit Stage
Client Planner Designer Constructor Supplier	Methods for Eco-Efficient Design Comparison of design alternatives Assessment against performance targets Communications between client & designers, e.g. LCADesign				
Owners Facility Managers Bldg Ops & Mgrs Occupants Developers R/Estate Brokers Investors		Methods for Rating New Buildings from Environmental AspectCommunication between stake-holders regarding level of green investment in building e.g. Green Star			
Owners Designers Bldg Op Mgrs Occupants			Methods for Sustainability-Oriented Operation Communication between stakeholders for building operation, e.g. NABERS		

The objective of this task is to compare the environmental impacts of the building under going refurbishment both before and after the refurbishment and to assist in the design of the refurbishment.

This project will apply the LCADesign; Green Star and NABERS tool to the client’s existing and re-designed building, providing performance assessments across a range of key ESD domains (e.g. water, energy, waste, indoor environment etc) during re-design and post-occupancy, as outlined in the table below.

	Original performance of building as a product - materials	*Re-design performance of building as a product - materials*	*In-service performance of building as operated*	*Redesigned in service performance of building as operated*
LCADesign	✓	✓		
Green Star			✓	✓
NABERS			✓	✓

A 3D CAD model of the building as it currently stands is an essential prerequisite to ensure it can be analyzed using LCADesign.

Assessment of existing building (B1)

The supplied 3D CAD model of the existing building will be assessed using LCADesign which may require some modifications to match the materials in the existing building at the required level of detail. The tasks include:

- Refinement of the 3D model as required
- Extension of the Life Cycle Inventory database as required
- Create any additional reasoning rules
- Analyse the results

The building will also be assessed using the GreenStar and NABERS rating tools.

Assessment of proposed (final) design of refurbished building (B2)

The assessment of the refurbishment design by LCADesign will require some additional features to be incorporated in the assessment procedure as well as the modified 3D CAD model. The tasks include:

- Refinement of the 3D model as required
- Improvements to LCADesign to incorporate measures of refurbishment (i.e. the parts of the building which can changed in the refurbishment design compared to those components which remain static from the first 3D CAD model).
- Extension of the Life Cycle Inventory database as required for any new materials/components
- Creation of any additional reasoning rules if necessary for refurbishment activities
- Analysis of the results

The final refurbishment design will also be assessed using the GreenStar and NABERS rating tools.

I.2.2 Deliverables

- Green building ratings of pre versus post refurbishment at whole building level and relevant sub-system level using Australian assessment tools (LCADesign, GreenStar and NABERS)
- Report on environmental assessments of both existing building and design for refurbishment

Note: 3D building model pre and post-refurbishment supplied by building owner. This project will be involved in the design process only to the extent of analysing 3D models provided by the building owner of the existing and re-designed building using 3 assessment tools. The Task has not been costed to allow participation in the (re-)design process

I.2.3 Key assumptions

A refurbishment demonstration project is identified.

- Whether the building owner can provide a 3D CAD model of existing building in a form which is usable by the project with limited changes
- Availability of similar 3D CAD model of design for refurbishment
- Timely availability of LCADesign, NABERS and GreenStar assessors and collaboration from Green Building Council of Australia (GBCA) – (Green Star) and Environment Australia (EA) – (NABERS) in undertaking assessments using their tools (not essential, but a nice-to-have)

Appendix II - Definitions

Biodegradable

Capable of decomposing in to elements found in nature with in a reasonably short period of time after customary disposal (Mendler and Odell, 2000)

Closed-loop recycling

Reclaiming or reusing waste water or process chemicals in an enclosed process in manufacturing. (Mendler and Odell, 2000)

Cradle-to-cradle

A term used in life cycle analysis to describe a material or product that is recycled in to a new product at the end of its defined life (Mendler and Odell, 2000)

Landfill

A site (hole in the ground) used for the purpose of disposing waste to land. In a modern sanitary landfill, the hole is lined so that materials will not escape and it is covered with layers of soil as it is progressively filled. When completely filled, it is capped and sealed with more soil and topsoil. (Hayes Environmental Consulting)

Non-renewable resource

A resource that cannot be replaced in the environment. Fossil fuels (coal, petroleum, natural gas) are examples of non renewable energy sources. (Mendler and Odell, 2000)

Recycle

Collecting and reprocessing a resource so it can be used again. An example is collecting aluminium cans, melting them down, and using the aluminium to make new cans or other aluminium products (U.S. Environmental Protection Agency, 2000)

Recycled content

The proportion of recycled material in a product.

Refuse

Describes all kinds of solid waste (Dunmore, 1985)

Regeneration

Renewal of sites or habitats that have become unfit for human, animal, or plant habitation to bring them back into productive use. (Gissen, 2002)

Remanufacturing

Remanufacturing involves the recovery of equipment or products for servicing, upgrading and re-sale as working systems. Potentially offers much higher environmental returns than recycling (Building Commission Sustainability)

Renewable resource

A resource naturally regenerated in the contemporary time frame.

Reuse

The recovery of a material for additional use without reprocessing (Mendler and Odell, 2000)

Salvage

Material recovered from solid waste for recycling (Dunmore, 1985)

Useful life

A time period from product commissioning to end-of-useful life for an application.

Appendix III - Reasoning rules for design of CH1

Notes:

- The bold items are the Object Reasoning Rules (ORRs)
- The ORRs are usually the objects in a 3D CAD model and also those which would be replaced as an entity
- The first few letters in the ORR name are LCADesign codes for easy identification
- The lines following the ORR name contain the Product Reasoning Rules
- The number with the Product Reasoning Rule name is the key to the Life Cycle Inventory database item
- PRRs are usually a single material

III.1 Rules for design 'CH1 existing'

EWPC00009 CH1-Spandrel Panel-30MPa-120kg/m3 reinforcement			
7043	CPWATU001	CH1-Concrete Precast Wall Tilt Up 30MPa Standard	Vo
8050	CPWATU003	CH1-Concrete Precast Wall Tilt Up Reinforcement 1	Vo
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plastic	(A
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Pl	(A
9702	PNWACM005	CH1-Painting Wall Concrete/Masonry External A	Ar
NWNE00001 CH1- Framed timber ducting - Craftwood painted			
7464	CAWALN001	CH1-Wall lining MDF	Ar
7464	CAWALN003	CH1-Wall lining MDF wall end	He
7899	PNWAFP001	CH1-Painting Wall FC/Plasterboard Internal Under	Ar
7899	PNWAFP006	CH1-Painting End of Wall FC/Plasterboard Internal Undercoat	He
9702	PNWAFP003	CH1-Painting Wall FC/Plasterboard Internal Finish	Ar
9702	PNWAFP007	CH1-Painting End of Wall FC/Plasterboard Internal Finish	He
8651	PTFDTF001	CH1-Timber frame for ducting	He 0*
NWMS00016 CH1-Partition Stud and Track-Glazed 60%-fixed			
7559	PTFDSF003	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7559	PTFDSF004	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7559	PTFDSF005	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7899	PNWAFP001	CH1-Painting Wall FC/Plasterboard Internal Under	Ar
9702	PNWAFP003	CH1-Painting Wall FC/Plasterboard Internal Finish	Ar
7559	PTFDSF001	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	He
7677	PLWAPB001	CH1-Plastering Wall PlasterBoard Standard Board 1	Ar
7565	WIFXST003	CH1-Framing screws for in wall fixed 6mm clear float glass	0.1
9041	WIFXST001	CH1-Glazing fixed in wall 6mm clear float glass	He
7384	WIFXST002	CH1-PVC glazing wedge for in wall fixed 6mm c	(Le
EWPC00010 CH1-Precast Concrete Mullion Panel -30MPa-120			
7043	CPWATU001	CH1-Concrete Precast Wall Tilt Up 30MPa Standard	Vo
8050	CPWATU003	CH1-Concrete Precast Wall Tilt Up Reinforcement 1	Vo
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plastic	(A
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Plastic	(A
9702	PNWACM005	CH1-Painting Wall Concrete/Masonry External Acrylic	Ar
NWCB00006 CH1-140 Blockwall including Craftwood finish			
7041	MLWACO003	CH1-140 Blockwork	Ar
9702	PNWACM003	CH1-Painting Wall Concrete/Masonry Internal semigloss acrylic one coat	Ar
7844	MLWACO004	CH1-140 Concrete wall filling	Ar
7313	CRWABR003	CH1-Concrete Reinforcement Block Wall Y Bar 3.	Ar
7464	CAWALN001	CH1-Wall lining MDF	Ar
7899	PNWAFP001	CH1-Painting Wall FC/Plasterboard Internal Undercoat	Ar
9702	PNWAFP003	CH1-Painting Wall FC/Plasterboard Internal Finish coat	Ar
WWAW00012 CH1-Fixed Light Frameless Windows-Tinted			
9041	WIFXAL008	CH1-Windows Fixed Aluminium Commercial Glazing 6m	He
7384	WIFXAL009	CH1-Windows Fixed Aluminium Commercial PVC glazing	2*
7253	WIFXAL016	CH1-Aluminium powder coated single sided framing single pane	2*
7316	WIFXAL010	CH1-Windows Fixed Aluminium Commercial Framing Sc	0.1
EWSC00016 CH1-Concrete External Wall-25MPa-120kg/m3 rei			
7043	CIWATF001	CH1-Concrete In-situ Wall 25MPa Readymixed Standard	Vo
8003	CFWAVS001	CH1-Concrete formply formwork wall vertical one side	Ar
7313	CRWABR001	CH1-Concrete Reinforcement Wall Bar R & Y Bar 120	Vo
8517	PLWACR001	CH1-Plastering Wall Cement Render (Standard) 1 Coat	Ar
9702	PNWACM005	CH1-Painting Wall Concrete/Masonry External Acrylic	Ar
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plastic	(A

8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Plastic
NWCB00007 CH1-140 Blockwall including paint finish		
9702	PNWACM003	CH1-Painting Wall Concrete/Masonry Internal semigloss acrylic one coat
7041	MLWACO003	CH1-140 Blockwork
7313	CRWABR003	CH1-Concrete Reinforcement Block Wall Y Bar 3.
7844	MLWACO004	CH1-140 Concrete wall filling
CLES00001 CH1-32 Mpa Concrete Encased Steel Column - Off f		
7043	CICITF001	CH1-Concrete In-situ Column Isolated 25MPa Readymix
8003	CFCISD001	CH1-Concrete Formwork Column Isolated Sides formply
9691	PNCLCM001	CH1-Painting Column Concrete/Masonry Internal Undercoat
9693	PNCLCM003	CH1-Painting Column Concrete/Masonry Internal semigloss acrylic all faces one coat
7677	PLCLPB001	CH1-Plasterboard column lining
8538	PLWAFU003	CH1-Plastering Column Furring Channel Metal 600mm
8050	CRCIBR001	CH1-Concrete Column Reinforcement
NDTC00008 CH1-Timber Internal Doors with Metal Frame, H		
9387	DRINTB001	CH1-Door Internal Timber Single door Flush Solid
8192	DRLTAN001	CH1-Door Lintel Angle Galvanised 100x75x10mm Bear
7330	DRHIBL001	CH1-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm
7519	JYDRFM001	CH1-Joinery Door Frame Single Steel-Zinc Aluminium
7898	PNDRTB013	CH1-Painting Door Timber External Prime Coat Acrylic
9702	PNDRTB015	CH1-Painting Door Timber External Finish Coat semigloss
NWSC00022 CH1-Concrete Internal wall-25MPa pumped-120kg		
7043	CIWATF001	CH1-Concrete In-situ Wall 25MPa Readymixed Standard
8003	CFWAVS001	CH1-Concrete formply formwork wall vertical one side
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plastic
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Pl
7313	CRWABR001	CH1-Concrete Reinforcement Wall Bar R & Y Bar 120
UFSB00009 CH1-Upstand Beam painted - ceramic glazed top		
7043	CIBATF001	CH1-Concrete In-situ Beam Attached 25MPa Readymixed Standard Mix Pumped
8003	CFBASI001	CH1-Concrete Formwork Beam Attached Soffit/Sides formply 17mm Class 3
8050	CRBABR001	CH1-Concrete Reinforcement Beam Attached Bar R & Y Bar 150kg/m3
8057	CRBABC001	CH1-Concrete Reinforcement Beam Attached Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component
8059	CRBABC003	CH1-Concrete Reinforcement Beam Attached Bar Chai
9672	TLFRCE001	CH1-Tiling Floor Ceramic over 300mm wide 300x300 Straight Joints 12.5mm Thick
7122	TLFRGR001	CH1-Tiling Floor Grouting Cement Mortar No Colour For 300x300mm tiles 12.5mm Thick
7899	PNBMCM001	CH1-Painting beam side concrete/masonry internal acrylic undercoat
9702	PNBMCM002	CH1-Painting beam side concrete/masonry internal acrylic semigloss
NWMS00015 CH1-Partition Stud and Track-fixed 76mm wide		
7559	PTFDSF001	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7
7559	PTFDSF003	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7
7559	PTFDSF004	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7
7559	PTFDSF005	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7
7677	PLWAPB001	CH1-Plastering Wall PlasterBoard Standard Board 1
7899	PNWAFP001	CH1-Painting Wall FC/Plasterboard Internal Under
9702	PNWAFP003	CH1-Painting Wall FC/Plasterboard Internal Finish
EWWM00001 CH1-Grills with capping		
7317	MWHRSS001	CH1-Metalwork Handrail stainless steel capping
8192	MWHRGS005	CH1-Metalwork Handrail galvanized steel posts
8192	MWHRGS004	CH1-Metalwork Handrail galvanized steel grills
EDMF00005 CH1-External Aluminium Single Swing Door with		
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door
7253	DREXAL005	CH1-Door External door perimeter frame Including stiles, head and sill
7330	DRHIBL001	CH1-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm
7317	DREXAL006	CH1-Door External frame screws 8 Gauge Stainless Steel for Aluminium Door

		Perimeter frame	
7253	DREXAL007	CH1-Door External framing for single Aluminium Door	3.3
7384	DREXAL008	CH1-Door External PVC Glazing Wedge for single Aluminium Door	0.3
WWAW00015 CH1-Fixed Framed Windows			
9041	WIFXAL008	CH1-Windows Fixed Aluminium Commercial Glazing 6m	He
7384	WIFXAL009	CH1-Windows Fixed Aluminium Commercial PVC glazing	2*(
7316	WIFXAL005	CH1-Framing screws for in wall fixed 6mm clear float glass	0.1
7253	WIFXAL011	CH1-Aluminium powder coated framing single pane	4.5
NWMS00017 CH1-Partition Stud and Track-Glazed-fixed 76m			
7559	PTFDSF001	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	He
7559	PTFDSF003	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7559	PTFDSF004	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7559	PTFDSF005	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7565	WIFXST003	CH1-Framing screws for in wall fixed 6mm clear float glass	0.1
9041	WIFXST001	CH1-Glazing fixed in wall 6mm clear float glass	He
7384	WIFXST002	CH1-PVC glazing wedge for in wall fixed 6mm c	(Le
NDGS00003 CH1-Glazed Internal Double Doors			
7253	DREXAL001	CH1-Door External framing for double AluminiumDoor	6.6
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door	(H
7384	DREXAL004	CH1-Door External PVC Glazing Wedge for double Aluminium Door	0.3
UFSB00010 CH1-32 Mpa Suspended Slab Complete			
7045	CISSTT001	CH1-Concrete In-situ Slab Suspended 32MPa Readymix	Vo
8003	CFSSSF001	CH1-Concrete Formwork Slab Suspended Suspended Soffits	Ar
8003	CFSSVE001	CH1-Concrete Formwork Slab Suspended Vertical Edge	4*Y
8050	CRSSBR001	CH1-Concrete Reinforcement Slab Suspended Bar	Vo
8057	CRSGBC001	CH1-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8059	CRBABC003	CH1-Concrete Reinforcement Beam Attached Bar Chair	(A
8059	CRSGCB001	CH1-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to suit 40 to 100mm chairs One every 0.9m2 Plan area Galvanised Steel	(A
WWNE00001 CH1 - Empty window			
9041	WIOREM001	CH1 - Empty window	0.0
CFFN00005 CH1-Suspended Ceiling-1200x600 M/R 1200mm centre			
9049	SCEGAT001	CH1 (Need Another)-Suspended Ceiling Powder Coated Aluminium Components for Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Main Tee, Cross Tee, Wall Angle	Ar
7823	SCEGAT003	CH1-Suspended Ceiling Galvanised Steel Components For Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Suspension Rod, Suspension Clip, Main Runner Joiner, Suspension Rod Hanger	Ar
8506	SCEGAT004	CH1-Suspended Ceiling Plasterboard Component-13mm Standard for Exposed Grid Aluminium Two Way 1200x600 Grid For Prefinished Plasterboard Panel System	Ar
9691	PNEGAT001	CH1-Painting Under Coat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
7889	PNEGAT002	CH1-Painting Finish Coat Flat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
NSTS00004 CH1-Laminated Finish timber framed toilet par			
7559	PTFDSF001	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7	He
8761	PTFSBV002	CH1-Laminate	Ar
7330	DRHIBL001	CH1-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm	0.5
7466	CAWALN002	CH1-Wall particleboard partition	Ar
SCFC00005 CH1-Reo Concrete Dual Flight 45/200 Timber Rail			
7043	CISRTF001	CH1-Concrete In-situ Stairs 25MPa Readymixed Stan	2.7
8003	CFSRRI001	CH1-Concrete Formwork Stairs Risers formply 17mm	16
8003	CFSRSF001	CH1-Concrete Formwork Stairs Suspended Soffit for	23
8003	CFSRSO001	CH1-Concrete Formwork Stairs Stringer w/stair pro	32
8050	CRSRBR001	CH1-Concrete Reinforcement Stairs Bar R & Y Bar 1	32
8192	MWHRGS003	CH1-Metalwork Handrail Galvanized Steel 50 x 10mm	0.6

NWSC00023 CH1-Concrete Internal granite wall-25MPa pump		
7043	CIWATF001	CH1-Concrete In-situ Wall 25MPa Readymixed Standard
7313	CRWABR001	CH1-Concrete Reinforcement Wall Bar R & Y Bar 120
8003	CFWAVS001	CH1-Concrete formply formwork wall vertical one side
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plastic
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Pl
NSTS00003 CH1-Laminated Finish timber framed toilet par		
7559	PTFDSF001	CH1-Partitions Fixed Steel Frame Non-Fire Rated 7
8761	PTFSBV002	CH1-Laminate
7466	CAWALN002	CH1-Wall particleboard partition
SFPC00005 CH1-Toilet Suite White Porcelain-Pan & Cistern		
8329	PBTOCI001	CH1-Plumbing Toilet Cistern White Porcelain Dual
9671	PBTOPA001	CH1-Plumbing Toilet Pan White Porcelain Standard
8949	PBTOST001	CH1-Plumbing Toilet Seat Plastic 2 Flap Quality W
9002	PBTOWP001	CH1-Plumbing Toilet Waste Piping UPVC 100mm D
7794	PBTOWS001	CH1-Plumbing Toilet Water Supply Copper 15mm
FTBC00002 CH1-Bench Cupboard Unit Laminated		
7464	JYVULP003	Joinery Vanity Unit Laminated Particleboard 750 Highx1500 Longx450 Deep MDF Component 33mm Thick Bench Top 16mm Gables, Shelf, Kick, Doors
7464	JYVULP004	Joinery Vanity Unit Laminated Particleboard 750 Highx1500 Longx450 Deep Hardboard Backing Component 6.4mm Thick
7464	JYVULP001	Joinery Vanity Unit Laminated Particleboard 750 Highx1500 Longx450 Deep Laminate Component 1.22mm thick
FFCT00004 CH1-Floor Covering-Ceramic Tiles-Mortar Bed-M		
9672	TLFRCE001	CH1-Tiling Floor Ceramic over 300mm wide 300x300 Straight Joints 12.5mm Thick
7122	TLFRGR001	CH1-Tiling Floor Grouting Cement Mortar No Colour For 300x300mm tiles 12.5mm Thick
7122	TLFRBD001	CH1-Tiling Floor Bed 20mm thick Cement Mortar For 300x300mm tiles
EDAU00003 CH1-Glazed Automatic Entry Door		
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door
7253	DREXAL005	CH1-Door External door perimeter frame Including stiles, head and sill
FFVY00003 CH1-Sheet Vinyl with welded joints - 100mm be		
9780	PFFRVI002	CH1-Sheet vinyl with 100mm skirting
FFTB00001 CH1-Floating Timber		
8537	PFFRFF003	CH1-Timber floating floor base
7462	PFFRFF002	CH1-Timber floating floor timber
9702	PFFRFF001	CH1 (Required New LCI Code as 9704)-Timber floating floor finish
FFCP00004 CH1-Floor Covering-Carpet Polypropylene Broad		
9774	PFFRBC001	CH1-Paving/Floorcoverings Floor Broadloom Carpet
8810	PFFRUY001	CH1-Paving/Floorcoverings Floor Underlay Vulcanised
7253	PFFRGR001	CH1-Paving/Floorcoverings Floor Grip Rod 33x7mm P
7313	PFFRGR002	CH1-Paving/Floorcoverings Floor Grip Rod Steel Na
FFNE00002 CH1-Painted epoxy		
9702	PFFRIF001	CH1-Floor painted epoxy
WWAW00011 CH1-Fixed Light Frameless Windows		
9041	WIFXAL008	CH1-Windows Fixed Aluminium Commercial Glazing 6m
7384	WIFXAL009	CH1-Windows Fixed Aluminium Commercial PVC glazing
7253	WIFXAL016	CH1-Aluminium powder coated single sided framing single pane
7316	WIFXAL010	CH1-Windows Fixed Aluminium Commercial Framing Sc
SFNE00002 CH1-Vanity Basin including taps, waste and waste outlet		
7794	PBVYTS001	CH1-Plumbing Vanity Tap set 3 Hole Basin Copper alloy (60/40) component
7916	PBVYWP001	CH1-Plumbing Vanity Waste Piping UPVC 50mm Diameter 2.2mm thick 3m long
7794	PBVYWS001	CH1-Plumbing Vanity Water Supply Copper 15mm Diameter 0.91 mm thick 2 at 3m long Bracket to masonry Pipe

7794	PBVYBN001	CH1-Vanity Basin	2.0
7780	PBVYWO001	CH1-Plumbing vanity waste outlet brass 50mm diameter chrome plated component	0.0
9100	PBVYWO002	CH1-Plumbing Vanity Waste Outlet Brass 50mm Diameter Brass Component including plug	0.3
SBGS00005 CH1-Concrete Ground Slab-20MPa pumped-100kg/m			
7041	CISGTY001	CH1-Concrete In-situ Slab Ground 20MPa Readymixed Standard Mix Pumped	Vo
8003	CFSGSS001	CH1-Concrete Formwork Slab Ground Slab Sides formply 17mm Class 5 All Sides	4*
8198	CISGMB001	CH1-Concrete In-situ Slab Ground Moisture barrier Polythene 200um thick	Ar
8050	CRSGBR001	CH1-Concrete Reinforcement Slab Ground Bar R & Y Bar 100kg/m3	Vo
8057	CRSGBC001	CH1-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8059	CRSGBC003	CH1-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Plastic Tip Polyethylene 2.4mm thick sleeve 25mm Long	(A
8059	CRSGCB001	CH1-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to suit 40 to 100mm chairs One every 0.9m2 Plan area Galvanised Steel	(A
EWBW00010 CH1-Single 110mm thick Skin Brickwork			
8153	MBWACY001	CH1-Masonry Brickwork Wall Clay Bricks Common Sin	Ar
8153	MBWACY003	CH1-Mortar Masonry Brickwork Wall Clay Bricks Common	Ar
7246	MBWADP001	CH1-Masonry Brickwork Wall Damp Proof Course Alum	Le
UFSB00011 CH1-Concrete Beams - 25 MPa-pumped - 150kg/m3			
7043	CIBATF001	CH1-Concrete In-situ Beam Attached 25MPa Readymixed Standard Mix Pumped	Vo
8003	CFBASI001	CH1-Concrete Formwork Beam Attached Soffit/Sides formply 17mm Class 3	31
8050	CRBABR001	CH1-Concrete Reinforcement Beam Attached Bar R & Y Bar 150kg/m3	Vo
8057	CRBABC001	CH1-Concrete Reinforcement Beam Attached Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8059	CRBABC003	CH1-Concrete Reinforcement Beam Attached Bar Chai	(A
SFUR00005 CH1-Wall Mounted-Vitreous China Body-Sanitary Supply Copper-UPVC Waste Pipe			
9671	PBURWM001	CH1-Plumbing urinal white porcelain standard	17
9002	PBTOWP001	CH1-Plumbing Toilet Waste Piping UPVC 100mm D	3.3
7794	PBTOWS001	CH1-Plumbing Toilet Water Supply Copper 15mm	1.0
WWTW00002 CH1-Timber frame and louvres			
9210	WIFXTB003	CH1-Timber frame for louvres	(2* 15
9210	WIFXTB004	CH1-Timber louvres	(R 1)*
WWTW00001 CH1-Timber Framed Windows			
9210	WIFXTB002	CH1-Timber frame for fixed 6mm clear float gl	He
9041	WIFXTB001	CH1-Glazing fixed 6 mm clear float glass sing	W
RFCC00004 CH1-Reinforced concrete roof Complete - Trafficable			
7045	CISSTT001	CH1-Concrete In-situ Slab Suspended 32MPa Readymi	Vo
8003	CFSSSF001	CH1-Concrete Formwork Slab Suspended Suspended Soffits	Ar
8003	CFSSVE001	CH1-Concrete Formwork Slab Suspended Vertical Edge	4*
8050	CRSSBR001	CH1-Concrete Reinforcement Slab Suspended Bar	Vo
8057	CRSGBC001	CH1-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8059	CRBABC003	CH1-Concrete Reinforcement Beam Attached Bar Chai	(A
8059	CRSGCB001	CH1-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to suit 40 to 100mm chairs One every 0.9m2 Plan area Galvanised Steel	(A
EDMF00006 CH1-External Aluminium Double Swing Door with			
7253	DREXAL001	CH1-Door External framing for double Aluminium Door	6.6
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door	(H
7384	DREXAL004	CH1-Door External PVC Glazing Wedge for double Aluminium Door	0.3
7253	DREXAL005	CH1-Door External door perimeter frame Including stiles, head and sill	3.2
7317	DREXAL006	CH1-Door External frame screws 8 Gauge Stainless Steel for Aluminium Door Perimeter frame	0.4
7330	DRHIBL001	CH1-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm	0.5

FFVY00002 CH1-Sheet Vinyl with welded joints		
8047	PFFRVI001	CH1-Sheet Vinyl Finish
CFAC00001 CH1-Suspended Acoustic Ceiling-1200x600 M/R		
9049	SCEGAT001	CH1 (Need Another)-Suspended Ceiling Powder Coated Aluminium Components for Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Main Tee, Cross Tee, Wall Angle
7823	SCEGAT003	CH1-Suspended Ceiling Galvanised Steel Components For Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Suspension Rod, Suspension Clip, Main Runner Joiner, Suspension Rod Hanger
8506	SCEGAT004	CH1-Suspended Ceiling Plasterboard Component-13mm Standard for Exposed Grid Aluminium Two Way 1200x600 Grid For Prefinished Plasterboard Panel System
9691	PNEGAT001	CH1-Painting Under Coat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid
7889	PNEGAT002	CH1-Painting Finish Coat Flat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid
RFCS00001 CH1-Metal deck roof		
8192	RFSLMD003	CH1-Roof metal deck joists
7586	RFSLMD001	CH1-Roof metal deck
9178	RFSLMD002	CH1-Roof metal deck fixings screws
SFSH00002 CH1-Shower complete including base, taps, rose, waste and water supply		
9041	PBSHWA001	CH1-Shower walls glass
7794	PBVYWS001	CH1-Plumbing Vanity Water Supply Copper 15mm Diameter 0.91 mm thick 2 at 3m long Bracket to masonry Pipe
9100	PBVYWO002	CH1-Plumbing Vanity Waste Outlet Brass 50mm Diameter Brass Component including plug
7916	PBVYWP001	CH1-Plumbing Vanity Waste Piping UPVC 50mm Diameter 2.2mm thick 3m long
7916	PBSHBS001	CH1-Shower base PVC
8330	PBSHWA002	CH1-Shower walls tiled
7695	PBSHWA003	CH1-Shower walls tile backing
7122	PBSHWA004	CH1-Shower walls tile grout
7794	PBVYTS001	CH1-Plumbing Vanity Tap set 3 Hole Basin Copper alloy (60/40) component
7780	PBVYWO001	CH1-Plumbing vanity waste outlet brass 50mm diameter chrome plated component
CFPL00002 CH1-Plasterboard Ceiling Lining		
7899	PNWAFP001	CH1-Painting Wall FC/Plasterboard Internal Under
9702	PNWAFP003	CH1-Painting Wall FC/Plasterboard Internal Finish
7677	PLWAPB001	CH1-Plastering Wall PlasterBoard Standard Board 1

III.2 Rules for design 'CH1 existing for lower impact materials'

EWPC00011 CH1 E-Spandrel Panel-30MPa-120kg/m3 reinforci			
7075	CPWATU004	CH1 E-Concrete Precast Wall Tilt Up Reinforcement 1	Vo
9694	PNWACM006	CH1 E-Painting Wall Concrete/Masonry External A	Ar
7102	CPWATU005	CH1 E-Concrete Precast Wall Tilt Up 30MPa Standard	Vo
8058	CRWABC004	CH1 E-Concrete Reinforcement Wall Bar Chairs Plasti	(A
8058	CRWABC005	CH1 E-Concrete Reinforcement Wall Bar Chairs Pl	(A
NWNE00002 CH1 E- Framed timber ducting - Craftwood painted			
7464	CAWALN001	CH1-Wall lining MDF	Ar
7464	CAWALN003	CH1-Wall lining MDF wall end	He
8651	PTFDTF001	CH1-Timber frame for ducting	He 0*
7893	PNWAFP004	CH1 E-Painting Wall FC/Plasterboard Internal Under	Ar
9693	PNWAFP005	CH1 E-Painting Wall FC/Plasterboard Internal Finish	Ar
7893	PNWAFP008	CH1 E-Painting End of Wall FC/Plasterboard Internal Undercoat	He
9693	PNWAFP009	CH1 E-Painting End of Wall FC/Plasterboard Internal Finish	He
8651	PTFDTF001	CH1-Timber frame for ducting	He 0*
8651	PTFDTF001	CH1-Timber frame for ducting	He 0*
NWMS00019 CH1 E-Partition Stud and Track-Glazed 60%-fixed			
7677	PLWAPB001	CH1-Plastering Wall PlasterBoard Standard Board 1	Ar
7893	PNWAFP004	CH1 E-Painting Wall FC/Plasterboard Internal Under	Ar
9693	PNWAFP005	CH1 E-Painting Wall FC/Plasterboard Internal Finish	Ar
7566	PTFDSF006	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	He
7184	WIFXST004	CH1 E-Framing screws for in wall fixed 6mm clear float glas	0.1
9041	WIFXST001	CH1-Glazing fixed in wall 6mm clear float gla	He
7918	WIFXST005	CH1 E-PVC glazing wedge for in wall fixed 6mm c	(Le
7566	PTFDSF007	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7566	PTFDSF008	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7566	PTFDSF009	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
EWPC00012 CH1 E-Precast Concrete Mullion Panel -30MPa-120			
7075	CPWATU004	CH1 E-Concrete Precast Wall Tilt Up Reinforcement 1	Vo
9694	PNWACM006	CH1 E-Painting Wall Concrete/Masonry External A	Ar
7102	CPWATU005	CH1 E-Concrete Precast Wall Tilt Up 30MPa Standard	Vo
8058	CRWABC004	CH1 E-Concrete Reinforcement Wall Bar Chairs Plasti	(A
8058	CRWABC005	CH1 E-Concrete Reinforcement Wall Bar Chairs Pl	(A
NWCB00009 CH1 E-140 Blockwall including Craftwood finish			
7100	MLWACO005	CH1 E-140 Blockwork	Ar
7068	MLWACO006	CH1 E-140 Concrete wall filling	Ar
7371	CRWABR005	CH1 E-Concrete Reinforcement Block Wall Y Bar 3.	Ar
9693	PNWACM007	CH1 E-Painting Wall Concrete/Masonry Internal semigloss acrylic one coat	Ar
7893	PNWAFP004	CH1 E-Painting Wall FC/Plasterboard Internal Under	Ar
9693	PNWAFP005	CH1 E-Painting Wall FC/Plasterboard Internal Finish	Ar
7464	CAWALN001	CH1-Wall lining MDF	Ar
WWAW00014 CH1 E-Fixed Light Frameless Windows-Tinted			
9041	WIFXAL013	CH1 E (Need Reused)-Windows Fixed Aluminium Commercial Glazing 6m	He
7918	WIFXAL014	CH1 E-Windows Fixed Aluminium Commercial PVC glazin	2*
7586	WIFXAL017	CH1 E-Aluminium powder coated single sided framing single pane	2*
7316	WIFXAL010	CH1-Windows Fixed Aluminium Commercial Framing Sc	0.1
EWSC00017 CH1 E-Concrete External Wall-25MPa-120kg/m3 rei			
8517	PLWACR002	CH1 E-Plastering Wall Cement Render (Standard) 1 Co	Ar
9694	PNWACM006	CH1 E-Painting Wall Concrete/Masonry External A	Ar
7102	CIWATF002	CH1 E-Concrete In-situ Wall 25MPa Readymixed Standa	Vo

8058	CRWABC004	CH1 E-Concrete Reinforcement Wall Bar Chairs Plasti
8058	CRWABC005	CH1 E-Concrete Reinforcement Wall Bar Chairs Pl
7371	CRWABR004	CH1 E-Concrete Reinforcement Wall Bar R & Y Bar 120
8002	CFWAVS004	CH1 E-Concrete formply formwork wall vertical one side
NWCB00008 CH1 E-140 Blockwall including paint finish		
7100	MLWACO005	CH1 E-140 Blockwork
7068	MLWACO006	CH1 E-140 Concrete wall filling
7371	CRWABR005	CH1 E-Concrete Reinforcement Block Wall Y Bar 3.
9693	PNWACM007	CH1 E-Painting Wall Concrete/Masonry Internal semigloss acrylic one coat
CLES00002 CH1 E-32 Mpa Concr Encased Steel Column - Off f		
9691	PNCLCM001	CH1-Painting Column Concrete/Masonry Internal Und
7675	PLCLPB002	CH1 E-Plasterboard column lining
7185	PLWAFU004	CH1 E-Plastering Column Furring Channel Metal 600mm
7075	CRCIBR002	CH1 E-Concrete Column Reinforcement
7102	CICITF002	CH1 E-Concrete In-situ Column Isolated 25MPa Readym
8002	CFCISD002	CH1 E-Concrete Formwork Column Isolated Sides formp
9693	PNCLCM003	CH1-Painting Column Concrete/Masonry Internal semigloss acrylic all faces one coat
NDTC00009 CH1 E-Timber Internal Doors with Metal Frame, H		
7483	DRINTB002	CH1 E-Door Internal Timber Single door Flush Solid
7540	DRLTAN002	CH1 E-Door Lintel Angle Galvinised 100x75x10mm Bear
7182	DRHIBL002	CH1 E-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm
8344	JYDRFM002	CH1 E-Joinery Door Frame Single Steel-Zinc Aluminiu
7894	PNDRTB016	CH1E-Painting Door Timber External Prime Coat Acry
9693	PNDRTB017	CH1E-Painting Door Timber External Finish Coat sem
NWSC00025 CH1 E-Concrete Internal wall-25MPa pumped-120kg		
7043	CIWATF001	CH1-Concrete In-situ Wall 25MPa Readymixed Standa
8003	CFWAVS001	CH1-Concrete formply formwork wall vertical one side
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plasti
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Pl
7313	CRWABR001	CH1-Concrete Reinforcement Wall Bar R & Y Bar 120
UFSB00012 CH1 E-Upstand Beam painted - ceramic glazed top		
8002	CFBASI002	CH1 E-Concrete Formwork Beam Attached Soffit/Sides formply 17mm Class 3
7075	CRBABR002	CH1 E-Concrete Reinforcement Beam Attached Bar R & Y Bar 150kg/m3
8058	CRBABC004	CH1 E-Concrete Reinforcement Beam Attached Bar Chairs Plastic Tipped 50mm Hig One every 0.9m2 Plan area Steel Component
8058	CRBABC005	CH1 E-Concrete Reinforcement Beam Attached Bar Chai
8330	TLFRCE002	CH1 E-Tiling Floor Ceramic over 300mm wide 300x300 Straight Joints 12.5mm Thick
7853	TLFRGR002	CH1 E-Tiling Floor Grouting Cement Mortar No Colour For 300x300mm tiles 12.5m Thick
7893	PNBMCM003	CH1 E-Painting beam side concrete/masonry internal acrylic undercoat
9693	PNBMCM004	CH1 E-Painting beam side concrete/masonry internal accrylic semigloss
7102	CIBATF002	CH1 E-Concrete In-situ Beam Attached 25MPa Readymixed Standard Mix Pumped
NWMS00018 CH1 E-Partition Stud and Track-fixed 76mm wide		
7677	PLWAPB001	CH1-Plastering Wall PlasterBoard Standard Board 1
7893	PNWAFP004	CH1 E-Painting Wall FC/Plasterboard Internal Under
9693	PNWAFP005	CH1 E-Painting Wall FC/Plasterboard Internal Finish
7566	PTFDSF006	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7
7566	PTFDSF007	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7
7566	PTFDSF008	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7
7566	PTFDSF009	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7
EWWM00002 CH1 E-Grills with capping		
8192	MWHRGS005	CH1-Metalwork Handrail galvanized steel posts
8192	MWHRGS004	CH1-Metalwork Handrail galvanized steel grills
9118	MWHRSS002	CH1 E-Metalwork Handrail stainless steel capping
EDMF00008 CH1 E-External Aluminium Single Swing Door with		
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door

7253	DREXAL005	CH1-Door External door perimeter frame Including stiles, head and sill	3.2
7253	DREXAL007	CH1-Door External framing for single AluminiumDoor	3.3
7182	DRHIBL002	CH1 E-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm	0.5
7565	DREXAL011	CH1 E-Door External frame screws 8 Gauge Stainless Steel for Aluminium Door Perimeter frame	0.4
7918	DREXAL012	CH1 E-Door External PVC Glazing Wedge for single Aluminium Door	0.3
WWAW00016 CH1 E-Fixed Framed Windows			
7316	WIFXAL005	CH1-Framing screws for in wall fixed 6mm clear float glas	0.1
7253	WIFXAL011	CH1-Aluminium powder coated framing single pane	4.5
9041	WIFXAL013	CH1 E (Need Reused)-Windows Fixed Aluminium Commercial Glazing 6m	He
7918	WIFXAL014	CH1 E-Windows Fixed Aluminium Commercial PVC glazin	2*(
NWMS00020 CH1 E-Partition Stud and Track-Glazed-fixed 76m			
7565	WIFXST003	CH1-Framing screws for in wall fixed 6mm clear float glas	0.1
9041	WIFXST001	CH1-Glazing fixed in wall 6mm clear float gla	He
7566	PTFDSF006	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	He
7918	WIFXST005	CH1 E-PVC glazing wedge for in wall fixed 6mm c	(Le
7566	PTFDSF007	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7566	PTFDSF008	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
7566	PTFDSF009	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	Le
UFSB00013 CH1 E-32 Mpa Suspended Slab Complete			
7103	CISSTT002	CH1 E-Concrete In-situ Slab Suspended 32MPa Readymi	Vo
8002	CFSSSF002	CH1 E-Concrete Formwork Slab Suspended Suspended So	Ar
8002	CFSSVE002	CH1 E-Concrete Formwork Slab Suspended Vertical Edg	4*V
8058	CRSGBC004	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(Ar
8058	CRSGBC005	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Plastic Tip Polyethylene 2.4mm thick sleeve 25mm Long	(Ar
8058	CRSGCB002	CH1 E-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to suit 40 to 100mm chairs One every 0.9m2 Plan area Galvinised Steel	(Ar
7075	CRSSBR002	CH1 E-Concrete Reinforcement Slab Suspended Bar R &	Vo
CFFN00006 CH1 E-Suspended Ceiling-1200x600 M/R 1200mm cen			
8506	SCEGAT004	CH1-Suspended Ceiling Plasterboard Component-13mm Standard for Exposed Grid Aluminium Two Way 1200x600 Grid For Prefinished Plasterboard Panel System	Ar
9691	PNEGAT001	CH1-Painting Under Coat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
9049	SCEGAT005	CH1 E-Suspended Ceiling Powder Coated Aluminium Components for Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Main Tee, Cross Tee, Wall Angle	Ar
7650	PNEGAT003	CH1 E-Painting Finish Coat Flat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
8161	SCEGAT006	CH1 E-Suspended Ceiling Galvanised Steel Componets For Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Suspension Rod, Suspension Clip, Main Runner Joiner, Suspension Rod Hanger	Ar
9049	SCEGAT005	CH1 E-Suspended Ceiling Powder Coated Aluminium Components for Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Main Tee, Cross Tee, Wall Angle	Ar
NSTS00006 CH1 E-Laminated Finish timber framed toilet par			
7466	CAWALN002	CH1-Wall particleboard partition	Ar
7566	PTFDSF006	CH1 E-Partitions Fixed Steel Frame Non-Fire Rated 7	He
8719	PTFSBV003	CH1 E-Laminate	Ar
7182	DRHIBL002	CH1 E-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm	0.5
SCFC00006 CH1 E-Reo Concre Dual Flight 45/200 Timber Rail			
8003	CFSRRI001	CH1-Concrete Formwork Stairs Risers formply 17mm	16
8003	CFSRSF001	CH1-Concrete Formwork Stairs Suspended Soffit for	23
8003	CFSRSO001	CH1-Concrete Formwork Stairs Stringer w/stair pro	32
8192	MWHRGS003	CH1-Metalwork Handrail Galvinized Steel 50 x 10mm	0.6
7102	CISRTF002	CH1 E-Concrete In-situ Stairs 25MPa Readymixed Stan	2.7
7075	CRSRBR002	CH1 E-Concrete Reinforcement Stairs Bar R & Y Bar 1	32

NWSC00026 CH1 E-Concrete Internal granite wall-25MPa pump		
7043	CIWATF001	CH1-Concrete In-situ Wall 25MPa Readymixed Standa
7313	CRWABR001	CH1-Concrete Reinforcement Wall Bar R & Y Bar 120
8003	CFWAVS001	CH1-Concrete formply formwork wall vertical one side
8057	CRWABC001	CH1-Concrete Reinforcement Wall Bar Chairs Plasti
8059	CRWABC003	CH1-Concrete Reinforcement Wall Bar Chairs Pl
FFCT00005 CH1 E-Floor Covering-Ceramic Tiles-Mortar Bed-M		
7122	TLFRBD001	CH1-Tiling Floor Bed 20mm thick Cement Mortar For 300x300mm tiles
8330	TLFRCE002	CH1 E-Tiling Floor Ceramic over 300mm wide 300x300 Straight Joints 12.5mm Thick
7853	TLFRGR002	CH1 E-Tiling Floor Grouting Cement Mortar No Colour For 300x300mm tiles 12.5mm Thick
FFVY00005 CH1 E-Sheet Vinyl with welded joints - 100mm be		
9780	PFFRVI002	CH1-Sheet vinyl with 100mm skirting
FFTB00002 CH1 E-Floating Timber		
9702	PFFRFF001	CH1 (Required New LCI Code as 9704)-Timber floating floor finish
8656	PFFRFF004	CH1 E-Timber floating floor timber
8651	PFFRFF005	CH1 E-Timber floating floor base
FFCP00005 CH1 E-Floor Covering-Carpet Polypropylene Broad		
7253	PFFRGR001	CH1-Paving/Floorcoverings Floor Grip Rod 33x7mm P
7313	PFFRGR002	CH1-Paving/Floorcoverings Floor Grip Rod Steel Na
9776	PFFRBC002	CH1 E-Paving/Floorcoverings Floor Broadloom Carpet
8842	PFFRUY002	CH1 E-Paving/Floorcoverings Floor Underlay Vulcanis
FFNE00003 CH1 E-Painted epoxy		
9693	PFFRIF002	CH1 E-Floor painted epoxy
WWAW00013 CH1 E-Fixed Light Frameless Windows		
9041	WIFXAL013	CH1 E (Need Reused)-Windows Fixed Aluminium Commercial Glazing 6m
7918	WIFXAL014	CH1 E-Windows Fixed Aluminium Commercial PVC glazin
7586	WIFXAL017	CH1 E-Aluminium powder coated single sided framing single pane
7316	WIFXAL010	CH1-Windows Fixed Aluminium Commercial Framing Sc
SFNE00003 CH1 E-Vanity Basin including taps, waste and wa		
7794	PBVYWS001	CH1-Plumbing Vanity Water Supply Copper 15mm Diameter 0.91 mm thick 2 at 3m long Bracket to masonry Pipe
7794	PBVYBN001	CH1-Vanity Basin
9100	PBVYWO002	CH1-Plumbing Vanity Waste Outlet Brass 50mm Diameter Brass Component includin plug
7916	PBVYWP002	CH1 E-Plumbing Vanity Waste Piping UPVC 50mm Diameter 2.2mm thick 3m long
7999	PBVYTS007	CH1 E-Plumbing Vanity Tap set 3 Hole Basin Copper alloy (60/40) component
7317	PBVYWO003	CH1 E-Plumbing vanity waste outlet brass 50mm diameter chrome plated component
SBGS00007 CH1 E-Concrete Ground Slab-20MPa pumped-100kg/m		
7100	CISGTY002	CH1 E-Concrete In-situ Slab Ground 20MPa Readymixed Standard Mix Pumped
8058	CRSGBC005	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm Hig One every 0.9m2 Plan area Plastic Tip Polyethylene 2.4mm thick sleeve 25mm Long
8058	CRSGCB002	CH1 E-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to su 40 to 100mm chairs One every 0.9m2 Plan area Galvinised Steel
8058	CRSGBC004	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm Hig One every 0.9m2 Plan area Steel Component
7075	CRSGBR002	CH1 E-Concrete Reinforcement Slab Ground Bar R & Y Bar 100kg/m3
8002	CFSGSS002	CH1 E-Concrete Formwork Slab Ground Slab Sides formply 17mm Class 5 All Sides
9192	CISGMB002	CH1E-Concrete In-situ Slab Ground Moisture barrier Polythene 200um thick
EWBW00013 CH1 E-Single 110mm thick Skin Brickwork		
7814	MBWACY007	CH1 E-Masonry Brickwork Wall Clay Bricks Common Sin
7814	MBWACY008	CH1 E-Mortar Masonry Brickwork Wall Clay Bricks Common
7586	MBWADP004	CH1 E-Masonry Brickwork Wall Damp Proof Course Alum
UFSB00014 CH1 E-Concrete Beams - 25 MPa-pumped - 150kg/m3		
7102	CIBATF002	CH1 E-Concrete In-situ Beam Attached 25MPa Readymixed Standard Mix Pumped

8002	CFBASI002	CH1 E-Concrete Formwork Beam Attached Soffit/Sides formply 17mm Class 3	31
8058	CRBABC004	CH1 E-Concrete Reinforcement Beam Attached Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8058	CRBABC005	CH1 E-Concrete Reinforcement Beam Attached Bar Chai	(A
7075	CRBABR002	CH1 E-Concrete Reinforcement Beam Attached Bar R & Y Bar 150kg/m3	Vo
WWTW00004 CH1 E-Timber frame and louvres			
9043	WIFXTB006	CH1 E-Timber frame for louvres	(2* 15
9043	WIFXTB007	CH1 E-Timber louvres	(R 1)*
WWTW00003 CH1 E-Timber Framed Windows			
9041	WIFXTB001	CH1-Glazing fixed 6 mm clear float glass sing	W
9043	WIFXTB005	CH1 E-Timber frame for fixed 6mm clear float gl	He
RFCC00006 CH1 E-Reinforced concrete roof Complete - Trafficable			
7103	CISSTT002	CH1 E-Concrete In-situ Slab Suspended 32MPa Readymi	Vo
8058	CRSGBC004	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Steel Component	(A
8058	CRSGBC005	CH1 E-Concrete Reinforcement Slab Ground Bar Chairs Plastic Tipped 50mm High One every 0.9m2 Plan area Plastic Tip Polyethylene 2.4mm thick sleeve 25mm Long	(A
8058	CRSGCB002	CH1 E-Concrete Reinforcement Slab Ground Bar Chair Base 155mm Diameter to suit 40 to 100mm chairs One every 0.9m2 Plan area Galvinised Steel	(A
7075	CRSSBR002	CH1 E-Concrete Reinforcement Slab Suspended Bar R &	Vo
8002	CFSSSF002	CH1 E-Concrete Formwork Slab Suspended Suspended So	Ar
8002	CFSSVE002	CH1 E-Concrete Formwork Slab Suspended Vertical Edg	4*V
EDMF00007 CH1 E-External Aluminium Double Swing Door with			
9041	DREXAL003	CH1-Door External 6mm clear glass for Aluminium Door	(H
7253	DREXAL005	CH1-Door External door perimeter frame Including stiles, head and sill	3.2
7918	DREXAL010	CH1 E-Door External PVC Glazing Wedge for double Aluminium Door	0.3
7586	DREXAL009	CH1 E-Door External framing for double AluminiumDoor	6.6
7182	DRHIBL002	CH1 E-Door Hinge Butt-Loose Pin Steel 100x75mm 3mm	0.5
7565	DREXAL011	CH1 E-Door External frame screws 8 Gauge Stainless Steel for Aluminium Door Perimeter frame	0.4
FFVY00004 CH1 E-Sheet Vinyl with welded joints			
9780	PFFRVI003	CH1 E-Sheet Vinyl Finish	Ar
CFAC00002 CH1 E-Suspended Acoustic Ceiling-1200x600 M/R 1			
9691	PNEGAT001	CH1-Painting Under Coat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
7650	PNEGAT003	CH1 E-Painting Finish Coat Flat Acrylic for Suspended Ceiling Exposed Grid Aluminium Two Way 1200x600 Grid	Ar
9049	SCEGAT005	CH1 E-Suspended Ceiling Powder Coated Aluminium Components for Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Main Tee, Cross Tee, Wall Angle	Ar
8161	SCEGAT006	CH1 E-Suspended Ceiling Galvanised Steel Componets For Exposed Grid Aluminium Two Way 1200x600 Grid Prefinished Plasterboard Panel System Includes-Suspension Rod, Suspension Clip, Main Runner Joiner, Suspension Rod Hanger	Ar
8506	SCEGAT004	CH1-Suspended Ceiling Plasterboard Component-13mm Standard for Exposed Grid Aluminium Two Way 1200x600 Grid For Prefinished Plasterboard Panel System	Ar
RFCS00002 CH1 E-Metal deck roof			
8192	RFSLMD003	CH1-Roof metal deck joists	(R 0.2
8588	RFSLMD004	CH1 E-Roof metal deck	Ar
7184	RFSLMD005	CH1 E-Roof metal deck fixings screws	(A
SFSH00003 CH1 E-Shower complete including base, taps, rose, waste and water supply			
9041	PBSHWA001	CH1-Shower walls glass	1.8
7794	PBVYWS001	CH1-Plumbing Vanity Water Supply Copper 15mm Diameter 0.91 mm thick 2 at 3m long Bracket to masonry Pipe	2.0
9100	PBVYWO002	CH1-Plumbing Vanity Waste Outlet Brass 50mm Diameter Brass Component including	0.3

		plug
7916	PBVYWP002	CH1 E-Plumbing Vanity Waste Piping UPVC 50mm Diameter 2.2mm thick 3m long
9180	PBSHBS002	CH1 E-Shower base PVC
9672	PBSHWA005	CH1 E-Shower walls tiled
8693	PBSHWA006	CH1 E-Shower walls tile backing
7853	PBSHWA007	CH1 E-Shower walls tile grout
7999	PBVYTS007	CH1 E-Plumbing Vanity Tap set 3 Hole Basin Copper alloy (60/40) component
7317	PBVYWO003	CH1 E-Plumbing vanity waste outlet brass 50mm diameter chrome plated component
CFPL00003 CH1 E-Plasterboard Ceiling Lining		
7675	PLWAPB003	CH1 E-Plastering Wall PlasterBoard Standard Board 1
7893	PNWAFP004	CH1 E-Painting Wall FC/Plasterboard Internal Under
9693	PNWAFP005	CH1 E-Painting Wall FC/Plasterboard Internal Finish

Appendix IV - Task 4: Initial Report on Design for Disassembly

Project Number 2003-028-B

REGENERATING CONSTRUCTION TO ENHANCE SUSTAINABILITY

Report:
Preliminary assessment of three design options for CH1 for Design for Disassembly

August 2005

Dr Philip Crowther
Queensland University of Technology
Brisbane

Introduction:

This report represents a preliminary assessment of the design for disassembly issues for three design options for Council House 1. Part One of the report presents a number of relevant design principles that may guide the further design development of the project. Part Two identifies particular possibilities within the design(s) and makes some recommendations for increasing the potential in the design for future disassembly for reuse and recycling.

The report refers to circulated documents of three design options dated 06/04/05.

The disassembly of buildings for the harvesting of materials and components is not widely practiced in the modern construction industry. Design for disassembly is the practice of incorporating into the initial design of the building allowance for the easy recovery of material in the future. CH1 provides the opportunity to design a building in which a plan for the future reuse and recycling of materials and component has been considered. Such consideration can reduce the future quantities of waste and increase levels of reuse and recycling.

PART ONE:

The Principles of Design for Disassembly (DFD):

The following list of 27 principles of design for disassembly have been developed from analysis of examples of buildings that have been disassembled for reuse and recycling, either by design/intent or otherwise. These principles represent common approaches to the design of buildings for future disassembly and future reuse and recycling of materials and components.

Attendance to these issues in further design development of the proposals for CH1 will assist in allowing for greater levels of material and component reuse and recycling, through ease of disassembly, in the future.

Materials:

- **Use recycled and recyclable materials - to allow for all levels of the recycling hierarchy, increased use of recycled materials will also encourage industry and government to develop new technologies for recycling, and to create larger support networks and markets for future recycling.**
- *MINIMISE THE NUMBER OF DIFFERENT TYPES OF MATERIALS* **- this will simplify the process of sorting during disassembly, and reduce transport to different recycling locations, and result in greater quantities of each material.**
- *AVOID TOXIC AND HAZARDOUS MATERIALS* **- this will reduce the potential for contaminating materials that are being sorted for recycling, and will reduce the potential for health risks that might otherwise discourage disassembly.**
- *AVOID COMPOSITE MATERIALS AND MAKE INSEPARABLE SUBASSEMBLIES FROM THE SAME MATERIAL* **- in this way large amounts of one material will not be contaminated by a small amount of a foreign material that can not be easily separated.**
- *AVOID SECONDARY FINISHES TO MATERIALS* **- such coatings may contaminate the base material and make recycling difficult, where possible use materials that provide their own suitable finish or use mechanically separable finishes (Note: some protective finishes such as galvanising may still on balance be desirable since they extend the service life of the component despite disassembly or recycling problems).**

Components and Systems:

- *MINIMISE THE NUMBER OF DIFFERENT TYPES OF COMPONENTS* **- this will simplify the process of sorting and reduce the number of different disassembly procedures to be undertaken, it will also make component reuse more attractive due to greater numbers of fewer components.**
- *USE MECHANICAL CONNECTIONS RATHER THAN CHEMICAL ONES* **- this will allow the easy separation of components and materials without force, reduce contamination of materials, and reduce damage to components.**
- *USE AN OPEN BUILDING SYSTEM WHERE PARTS OF THE BUILDING ARE MORE FREELY INTERCHANGEABLE AND LESS UNIQUE TO ONE APPLICATION* **- this will allow alterations in the building layout through relocation of component without significant modification.**
- *USE MODULAR DESIGN* **- use components and materials that are compatible with other systems both dimensionally and functionally. This type of modular co-ordination, that today we in some part take for granted, not only has assembly advantages, but clearly also has disassembly advantages, such as standardisation of disassembly procedure and a broader market for reused components.**

- *USE CONSTRUCTION TECHNOLOGIES THAT ARE COMPATIBLE WITH STANDARD, SIMPLE, AND 'LOW-TECH' BUILDING PRACTICE AND COMMON TOOLS* **- specialist technologies will make disassembly difficult to perform and a less attractive option, particularly for the user. Specialist technologies, materials, and systems that have limited application today may not be readily available in the future when a building is to be disassembled.**
- *SEPARATE THE STRUCTURE FROM THE CLADDING, INTERNAL WALLS, AND SERVICES* **- to allow for parallel disassembly such that some parts or systems of the building may be removed without affecting other parts. Most construction methods can be considered as being either a system of load bearing walls, or a system of separate structural frame and in-fill. The system of separate frame and in-fill is by far the more compatible of the two with a range of disassembly requirements.**
- *PROVIDE ACCESS TO ALL PARTS OF THE BUILDING AND TO ALL COMPONENTS* **- ease of access will allow ease of disassembly, allow access for disassembly from within the building if possible.**
- *MAKE COMPONENTS AND MATERIALS OF A SIZE THAT SUITS THE INTENDED MEANS OF HANDLING* **- allow for various handling operations during assembly, disassembly, transport, reprocessing, and re-assembly. The handling of building materials and components is an important consideration in any building, more so if the building is to be disassembled and components later re-assembled.**
- *PROVIDE A MEANS OF HANDLING AND LOCATING COMPONENTS DURING THE ASSEMBLY AND DISASSEMBLY PROCEDURE* **- handling may require points of attachment for lifting equipment as well as temporary supporting and locating devices. The provision of a means of handling components is not often considered in building design because the current approach within the building industry is that a component will only be handled once during the initial assembly.**
- *PROVIDE REALISTIC TOLERANCES TO ALLOW FOR MANOEUVRING DURING DISASSEMBLY* **- the repeated assembly and disassembly process may require greater tolerance than for the manufacture process or for a one-off assembly process.**
- *USE A MINIMUM NUMBER OF FASTENERS OR CONNECTORS* **- to allow for easy and quick disassembly and so that the disassembly procedure is not complex or difficult to understand. Such a principle will assist in the repair of the component or in the rebuilding of it, though it is not so relevant for the reclaiming (for recycling) of the material, which might be recovered by simply breaking the component.**
- *USE A MINIMUM NUMBER OF DIFFERENT TYPES OF FASTENERS OR CONNECTORS* **- to allow for a more standardised process of assembly and disassembly without the need for numerous different tools and operations.**
- *DESIGN JOINTS AND CONNECTORS TO WITHSTAND REPEATED USE* **- to minimise irreparable damage or distortion of components and materials during repeated assembly and disassembly procedures, to allow for the rigors of repeated assembly and disassembly.**
- *ALLOW FOR PARALLEL DISASSEMBLY RATHER THAN SEQUENTIAL DISASSEMBLY* **- so that components or materials can be removed without disrupting other components or materials, where this is not possible make the most reusable or 'valuable' parts of the building most accessible, to allow for maximum recovery of those components and materials that are most likely to be reused.**
- *USE A STRUCTURAL GRID* **- the grid dimension and orientation should be related to the materials used such that structural spans are designed to make the most efficient use of material type and allow coordinated relocating of**

components such as cladding. This will also result in more components of same/standard size, and the grid responds to issues of material efficiency.

- *USE PREFABRICATED SUBASSEMBLIES AND A SYSTEM OF MASS PRODUCTION* **- to reduce site work and allow greater control over component quality and conformity. The prefabrication of these components reduces the amount of on-site work required and thereby eases the process of assembly, and later disassembly, of the building.**
- *USE LIGHTWEIGHT MATERIALS AND COMPONENTS* **- this will make handling easier and quicker, making disassembly and reuse a more attractive option. This will also allow disassembly for regular maintenance and replacement of parts.**
- *PROVIDE SPARE PARTS AND ON-SITE STORAGE FOR THEM* **- particularly for custom designed parts, both to replace broken or damaged components and when required for minor alterations to the building design. Storage for spare components is an integral part of the building design.**

Information Management:

- *PROVIDE STANDARD AND PERMANENT IDENTIFICATION OF MATERIAL TYPES* **- many materials such as plastics are not easily identifiable and should be provided with a non-removable and non-contaminating identification mark to allow for future sorting, such a mark could provide information on material type, place and time or origin, structural capacity, toxic content, etc.**
- *PROVIDE PERMANENT IDENTIFICATION OF COMPONENT TYPE* **- in a co-ordinated way with material information and total building system information, ideally electronically readable to international standards.**
- *PERMANENTLY IDENTIFY POINTS OF DISASSEMBLY* **- so as not to be confused with other design features and to sustain knowledge on the component systems of the building. As well as indicating points of disassembly, it may be necessary to indicate disassembly procedures as instructions.**
- *RETAIN ALL INFORMATION ON THE BUILDING CONSTRUCTION SYSTEMS AND ASSEMBLY AND DISASSEMBLY PROCEDURES* **- efforts should be made to retain and update information such as 'as built' drawings including all reuse and recycling potentials as an assets register. The retention of such complete information about the whole building enhances its potential value for relocation, reuse, or recycling.**

PART TWO:

Levels of recycling - recycling hierarchy (identifying the options and possibilities in this proposal):

A number of level or hierarchies of recycling need to be considered for the future potential of materials and components. These include: reuse of component, repair/maintain component, recycling of component for the reuse of base material, recycling of material for manufacture of new material, combustion for energy use.

Adopted definitions (as per email exchange 25/7/05):

- **'"Reuse" refers to a second life for a building material or component without significant alteration or transformation.'**
- **'"Recycle" refers to the use of a salvaged material as feedstock for new material. Significant transformation and reprocessing is involved.'**

It must be noted that some of the options are more environmentally desirable than other due to differences in raw material consumption and energy use in the re-processing. As such, all efforts should be made to allow for the reuse of components in the future where it is reasonable and appropriate.

Recommendation:

Some components and materials of the building should be selected or designed such that they can be easily reused in the future, rather than simple recycled. In the case of CH1, those components most suitable to such consideration include internal wall partitioning systems, access flooring systems, and suspended ceiling grids. Services components may be reused within this building during minor retrofitting, but are unlikely to find long term reuse applications since their future removal is likely to be due to physical deterioration or provision of service that is no longer of a high enough quality. Cladding and structural elements and materials are unlikely to find reuse application in the future, but the large quantities of materials in these systems make them good candidates for recycling.

Design for disassembly will be most critical for internal fit-out and space planning components and materials, and to a lesser extent services components.

Time related building layers, the theory, and this design proposal (identifying the layers in this design):

Perhaps the greatest issue with respect to designing for the future disassembly of CH1 is the need to ensure that components and systems of the building that will have only a short service life can be easily removed and replaced in the future. That is to say, parts of the building with different service lives need to be easily disassembled from each other. It is quite likely that a retrofitted structural frame such as CH1 will undergo further retrofitting in the future. As such, any work done now should be mindful of future potential for alteration.

Typical life expectancies for different parts of an office building are:

- **Structural frame - from 40 to 100 years, typically 60 years**
- **Cladding, highly dependent on the system used, but often changed due to 'fashion' - 20 to 50 years.**

- **Services, dependent on the expected standard of service - 7 to 15 years**
- **Internal fit-out and space planning - 3 to 10 years**

Recommendation:

Individual systems of the building should be designed such that components of short service life can be removed and replaced without undue alteration to components or systems of longer service life. Locations requiring particular attention are likely to be the intersections of internal partitioning walls and suspended ceiling systems (Option 3) or raised access flooring systems (Options 1 and 2). It is at these points where services and space planning elements of different life expectancies intersect.

Comparing the DFD potential in each of the three options:

Of the three options presented fro CH1, as dated 06/04/05, none of them shows any greater or lesser capacity for design for disassembly at this stage of development. Considering the major differences between the designs as might impact on design for disassembly:

- **It is unlikely that the extension to the structural frame, proposed in Option 3, would be a suitable item/system for future reuse.**
- **Raised/access flooring systems, and suspended ceiling grid systems, are all equally suited to future reuse.**
- **There are no other substantial differences (in respect to DFD) between the three proposals.**

Recommendation:

Each of the three options has equal capacity for development for design for disassembly, to allow for increased rates of future reuse and recycling of materials and components.

Materials and Components with better DFD potential (for this design proposal):

The components used are most likely to find their way to being reused if they are of a type that is used in other buildings owned by the client. That is to say standardization of components across several buildings increases the capacity for future reuse

Recommendation:

If possible/appropriate, the space making systems and components (internal walls, flooring, ceilings), should be of a type that is in common use by the user/client in other locations or is likely to be used in other locations. This will allow greater flexibility of application and encourage the future relocation and reuse of components.

Similar consideration should be given to services components. Although they are more likely to become redundant due to mechanical or technical failure and obsolescence, thereby making future reuse less likely, service components may find reuse applications in other buildings in the future if they are compatible with other building systems (either existing or proposed).

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