Analysis software for **sustainable design**

Life Cycle Assessment: Base design

Executive Summary

In order to quantify and improve the design of the Lot 26 Fitzgerald a life cycle assessment (LCA) has been conducted. Three LCAs were conducted, each representing an alternative design:

- A business as usual or benchmark design, "Lot 26 Fitzgerald Brick Veneer, BCA Climate Zone 5, eg Perth"
- Base case design, "Lot 26 Fitzgerald Base design"
- Improved design with modeled recommendations, "Lot 26 Fitzgerald Improved design - Certificate"

Design life is a critical factor in LCAs of buildings and infrastructure. In this case, the estimated design life of the benchmark was 35 years whilst the maximum durability of the building is 150 years. The estimated design life for the subject building "Lot 26 Fitzgerald Base design" is 70 years whilst the maximum durability is 100 years.

The Global Warming Potential impact associated with the base case design totalled -55828 kgCO2e

Taking into account the functional units of the building, this is equivalent to -324 kgCO2e/year/occupant. This represents a 108% or 4,349 kgCO2e/year/occupant saving compared to the benchmark.

With recommendations a saving of 110% or 4,426 kgCO2e/year/occupant can be achieved.

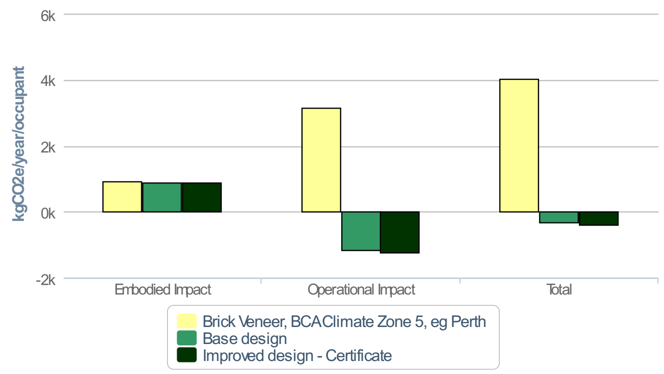
Having quantified the impacts associated with the base case design, this enabled a number of recommended design improvements to be identified. These are summarized below:

- Replace 50% cement with fly ash in concrete, saving 3.5t CO2e over the life of the building. Further research to be conducted to confirm fly ash is sourced locally.
- Reduce eaves on south facade to reduce materials and save 0.7t CO2e over the life of building. Expected cost reductions as well. Thermal performance differences, if applicable, were not modelled in this design.
- ACCEPTED - Increase ventilation to the rear of fridge will save 8.4t CO2e over the life of the building. The process of refrigeration is to remove heat from the inside of the unit and dissipate it to the outside. The condenser at the rear of the fridge is used to dissipate the heat, by increasing the ventilation to the rear of fridges, the efficiency can be increased by 25%. eTool have assumed a 15% increase in fridge efficiency by increasing ventilation in the kitchen cabinetry. The requirements are:
  • Additional airflow to the base of the rear of the fridge through a vent in the adjacent kickboard cabinetry
  • Ensuring the overhead cupboard above the fridge has a large gap between the wall and the rear of the cupboard (this is standard in most well designed kitchens)
- ACCEPTED - Internal clothes line will save 4.8t CO2e over the life of the building. 50% reduction in clothes drying energy assumed with installation of internal clothes hanger (eg hung from laundry roof).
- Use of natural gas for oven represents a total saving of 6t CO2e over the life of the building. More information about Gas vs electricity can be found at eTool's website http://etool.net.au/eblog/energy/gas-or-electricity/
- Hot water with solar gas instantaneous boost system. 33tCO2e saving over the life of the building. This reduces tank losses and the carbon intensity of the energy source. More information about Gas vs electricity can be found at eTool's website http://etool.net.au/eblog/energy/gas-or-electricity/
- A significant proportion of the impacts associated with the building is due to the recurring impacts of internal finishes (18tCO2e), with plasterboard and finishes for polished concrete floor being the biggest impacts. Some natural finishes (eg Timber ceiling) may reduce this requirements, or harder wearing coatings. Natural oil finishes can reduce impact of polished concrete floors.
- Use materials that can be deconstructed such as timber / steel frame floors, walls and roof systems in preference to materials that can't be re-located and re-used (eg, brick walls). If masonry walls are used, consider using a lime based mortar that enables the bricks or blocks to be cleaned and re-used after the building is demolished (rather than concrete mortar).
- Increase design life through higher density. By increasing density, the expected design life of the dwelling would increase. This is due to it becoming a less attractive target for redevelopment than lower density surrounding buildings. Shared walls also mean half the embodied impacts per dwelling for the wall. Is the building design fulfilling the maximum allowable density for the zoning?
- Future proofing. Further design options that would enable the house to be extended, retrofitted or modified for increased density or an alternative use. For example, enabling a dwelling to be split into two smaller living spaces at a later date by installing the required plumbing under the slab could significantly increase the expected design life of the dwelling by making it more attractive in the future.

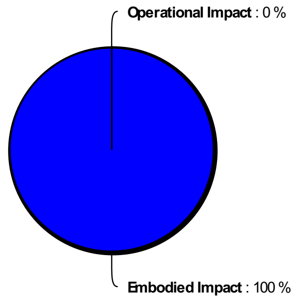
The following charts provide some further information regarding the comparative impacts of the three designs. A comparison has also been provided of the largest embodied and operational impacts. The detailed percentage split of impacts sources relating to the base case design have also been provided.

Total Life Cycle Global Warming Potential

Comparison of Global Warming Potential Profiles:

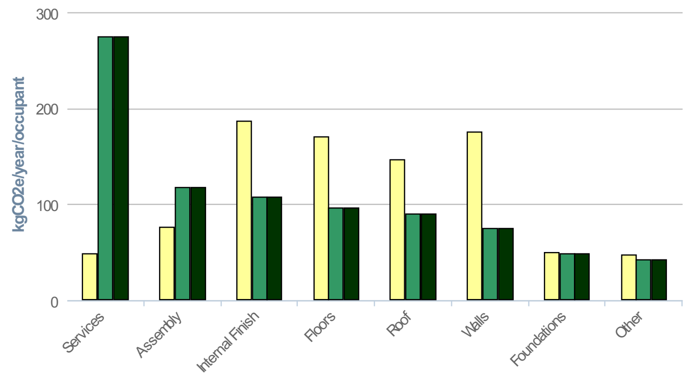


Total Global Warming Potential Profile for Base design

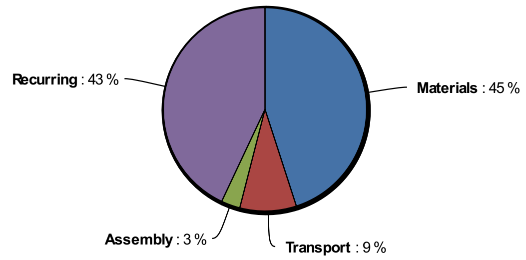


Embodied Global Warming Potential

Comparison of Embodied Global Warming Potential:

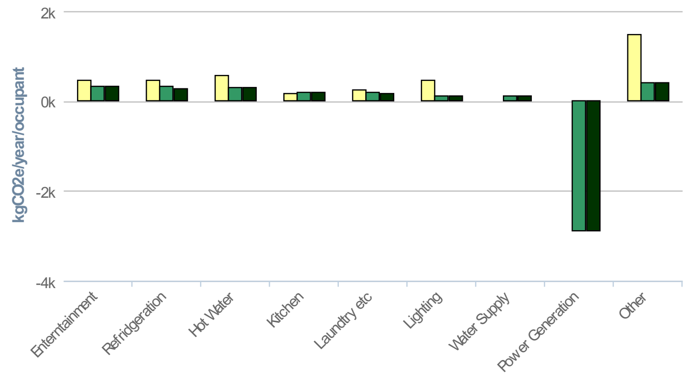


Embodied Global Warming Potential Profile for Base design

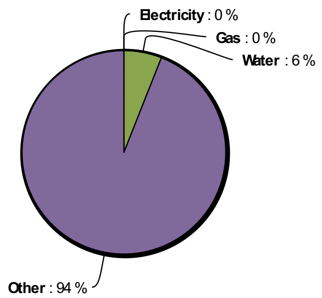


Operational Global Warming Potential

Comparison of Operational Global Warming Potential:



Operational Global Warming Potential Profile for Base design



Life Cycle Assessment Report Information

Introduction

Life Cycle Assessment (LCA) is a method used to determine the real cost and/or environmental impact of a product over its life. This LCA accounts for impacts and costs from cradle to grave (recycling environmental costs are not yet within the scope of eTool LCAs). In the case of buildings, the total life cycle energy consumption is made up of two components:

- Embodied Impacts
- Operational Impacts

This life cycle assessment compares the life cycle impacts of design options to a chosen benchmark. Where recommendations are made, their purpose is to reduce the impacts of the design.

LCA Goals

The goals of this life cycle assessment are to:

- Quantify the environmental impacts of the clients design (normal eTool assessments pay particular attention to CO2 equivalent emissions, CO2e)
- Compare these impacts against a typical 'business as usual' benchmark
- Provide recommendations that will ideally reduce the total impacts of the building
- Conduct this in a cost effective, auditable and repeatable manner

A typical eTool assessment allows reporting of numerous impacts. This report only details the Global Warming Potential impacts of the design options. It is the goal of eTool to estimate impacts with enough accuracy to compare different design options. The aim is to be vaguely right not precisely wrong. Estimating impacts to high levels of confidence requires detailed resources. In the case of buildings, this will usually be overshadowed by the influence of occupant behavior on operational impacts, or the actual building life that will deviate significantly from that estimated in this assessment. The assessment does not attempt to predict the affects of future changes to:

- Grid Power Sources (which hopefully by the time this building is actually nearing it's design life will be predominantly renewable)
- Inflation of building materials (for maintenance), labour costs or energy costs

The assessment therefore represents a snapshot in time, all else being equal, of the building performance.

LCA Scope

A number of impact categories have been isolated for reporting. Furthermore, the extent to which these categories are measured are detailed in the scope. Both the system boundaries and specific detail of the scope are found below

System Boundaries

The system boundary of the assessment is detailed in Figure 1. The system boundary is quite broad for this LCA, however the omission of demolition and recycling impacts must be noted as this has potential to be significant in an unbounded LCA. The eTool database does however store an estimated percentage of recyclable materials used in the construction of the building which can be reported on separately. Please contact us for more information.

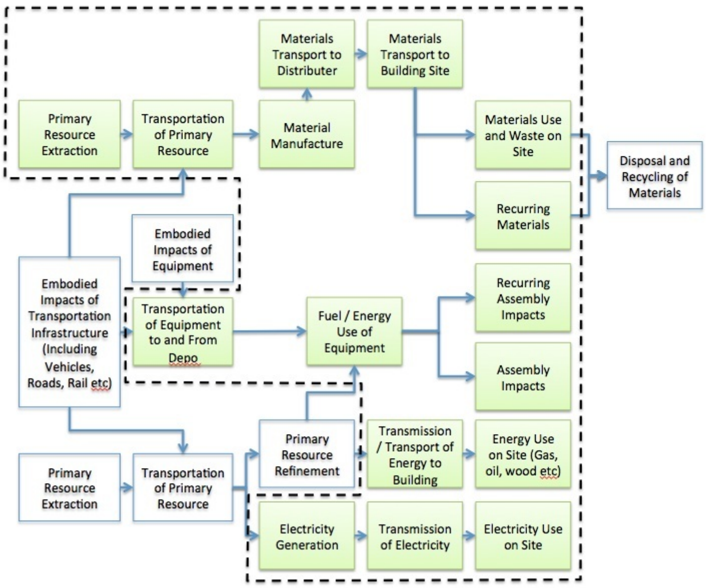


Figure 1: System Boundary of LCA

Specific Details of Scope

In relationship to the building envelope itself, the scope is further defined in Table 1. The impact categories are listed in the first column. The items falling in and out of scope are listed in detail. Factors that would greatly influence the total LCA GHG emissions of the designs include:

- Non permanent building fixtures such as furniture and appliances
- Operational Transportation (transportation of building occupants to and from the building to workplaces, recreational areas and retail outlets)
- Embodied carbon relating to building planning and sales

These factors listed are not considered significant to the conclusions of the LCA however please contact eTool if you would like to discuss how these impacts could be included in your assessment.

Category	In Scope		Out of Scope
Materials	Foundations • Foundations and Footings Floors • Slab or Posts • Structure • Insulation Walls • Structure • Doors • Windows • Insulation Roof • Structure • Covering • Ceiling • Gutters and Downpipes • Eves • Insulation Internal Finish • Paint • Floor Coverings • Cornices / Shadowlines • Wall Coverings (eg plaster) • Skirting Boards • Wet area floors and walls	External Finish • Shades • Security and Fly Screens • Paint • Wall coverings (eg renders) Services • Power • Plumbing • Communications • Sewerage • Air-conditioning and Heating • Lifts, elevators, access Fittings • Showers and baths • Lighting • Toilets • Shower Screens • Door handles and hardware • Taps • Bathroom and Laundry Sinks	Fittings • Kitchens Fittings • Cabinetry • All furnishings and appliances Landscaping • Paving • Retaining Walls • Gardening • Other Landscaping
Assembly	• Site Preparation and Earthmoving • Assembly energy associated with all material categories listed "In Scope" above		• Assembly energy associated with all material categories listed "Out of Scope" above
Recurring	• Replacement of Materials used in the categories listed "In Scope" above • Maintenance of materials used in the categories listed "In Scope" above • Recurring assembly impacts associated with maintaining and replacing building components in scope above.		• Any recurring impacts associated with out of scope materials or assembly.
Transport and Travel	• Transport of Materials associated with all material categories listed "In Scope" above • Transport of equipment and trade staff associated with all in scope assembly categories • Transport associated with recurring impacts		• Travel of building occupants after construction • Transport impacts associated with out of scope materials, assembly or recurring • Embodied impacts of transport methods (eg trade staff vehicles)
Operational	• Thermal Control • Hot Water • Refrigeration • Lighting • Cooking and other kitchen appliances • Laundry appliances • Entertainment and Communications • Workshop and garage	• Swimming pool • Domestic water supply • Domestic water treatment • Water pumps and bores • Small scale energy generation • Office / Work Stations • Personnel or Service Lift / Elevator	• Operational Transport Energy

Table 1: Specific detail of scope in relation to the building envelope.

Data Sources and Assumptions

Embodied Impacts

The life cycle inventory data chosen for this assessment includes:

- The default cradle to factory gate embodied impacts of materials are derived from the Inventory of Carbon and Energy (Mammond). Alternative LCI sources can be chosen in eTool and may have been implemented in whole or part in this report.
- Environment Australia for freight transportation GHG coefficients (Atech Group for Environment Australia, 2001)
- National Greenhouse Accounts Factors for GHG coefficients for fossil fuel combustion (Department of Climate Change and Energy, 2011)

In selecting data sources for eTool software, efforts have been made to identify significant items and cross check these against second or third sources for consistency and relevance. For example, the embodied GHG coefficient for clay bricks was cross checked against the Think Brick Australia – LCA of Brick Products (Energetics, 2010) for geographical relevance to Australian based LCAs and found to be appropriate.

Operational Impacts

For residential buildings, operational energy demand was modeled using a range of data sources. Australian primary energy consumption (ABARE, 2009) was interpreted to establish the average energy demand in Australia. This data was then cross referenced against other international residential building energy statistics (D&R International LTD, 2009 and US Energy Energy Information Administration, 2011). Once adjusted for climatic influence, the comparisons supported this method of estimating overall energy demand for average households. In the case of residential buildings, demand categories were then modelled using information from:

- Your Home Technical Manual (Department of Climate Change and Energy Efficiency, 2010)
- Baseline Energy Estimates 1990 – 2020 (Department of the Environment, Water, Heritage and the Arts, 2008)
- Energy use in Provision and Consumption of Urban Water in Australia and New Zealand (Kenway, et al., 2008)
- Nationwide House Energy Rating Scheme (NatHERS) starbands (www.nathers.gov.au) for average thermal performance

In the case of commercial buildings, operational energy demand was bencharked using the following sources:

- Sustainability in the Commercial Property Sector (Department of Environment and Climate Change NSW)
- NABERS Office Reverse Calculator
- Actual commercial buildings energy consumption (both predictive and surveyed data)

Functional Units

In order to normalise assessments between building types the impacts were measured per occupant. Furthermore, in order to normalise assessments between different building ages, the impacts were measured per year.

The Total Global Warming Potential for each of the designs assessed is outlined below:

- Base design: -55828 kgCO2e
- Brick Veneer, BCA Climate Zone 5, eg Perth: 334,079 kgCO2e
- Improved design - Certificate: -68982 kgCO2e

The design life of buildings has a very large effect on their comparable sustainability. Although difficult to predict, eTool uses a methodology aimed at producing fair and repeatable comparisons between building designs. Individual building life spans will deviate significantly from the design lives calculated using this methodology, however the aim is to predict the mean expected life of all buildings with similar characteristics and circumstances.

Although studies that quantify the actual life span of buildings are lacking, the reasons for demolition of buildings are quite well documented. Studies conducted in Australia (Kapambwe, Ximenes, F, Vinden, & Keenan, 2009) and the US (Athena Institute, 2004) indicate that less than 10% of buildings are demolished due to reaching the end of their strutural service life. It is other factors that usually dictate service life, namely:

- Redevelopment for economic reasons (surrounding land has increased in value to the extent that it is more profitable to increase the density or use of the buliding)
- Redevelopment for aesthetic reasons (the building is no longer in fasion)
- Fire or other disaster

For this reason the following characteristics are also considered when estimating design life:

- Building density
- Density of the surrounding suburb
- Design quality

Best practice building design attempts to match the durability with the redevelopment potential of the building.

In this case, the estimated design life of the benchmark was 35 years whilst the maximum durability of the building is 150 years. The estimated design life for the subject building "Lot 26 Fitzgerald Base design" is 70 years whilst the maximum durability is 100 years.

The eTool estimated design lives often differ compared to industry perceptions of building life span. Architects in Australia for example expect detached residential buildings to last over 60 years (Kapambwe, Ximenes, F, Vinden, & Keenan, 2009).

Life Cycle Inventory

A summary of LCI outputs is found on the first page of this report. For further details on the life cycle inventory (both inputs and outputs) which are all stored in the eTool database please contact eTool.

eTool Design Recommendations

- Replace 50% cement with fly ash in concrete, saving 3.5t CO2e over the life of the building. Further research to be conducted to confirm fly ash is sourced locally.
- Reduce eaves on south facade to reduce materials and save 0.7t CO2e over the life of building. Expected cost reductions as well. Thermal performance differences, if applicable, were not modelled in this design.
- ACCEPTED - Increase ventilation to the rear of fridge will save 8.4t CO2e over the life of the building. The process of refrigeration is to remove heat from the inside of the unit and dissipate it to the outside. The condenser at the rear of the fridge is used to dissipate the heat, by increasing the ventilation to the rear of fridges, the efficiency can be increased by 25%. eTool have assumed a 15% increase in fridge efficiency by increasing ventilation in the kitchen cabinetry. The requirements are:
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Sensitivity

Estimating impacts to high levels of confidence requires costly resources, and in the case of buildings, is very likely to be overshadowed by the influence of occupant behaviour on operational impacts, or the actual design life (both of which on a case by case basis will deviate significantly from the estimates in the LCA). eToolLCA software aims to be vaguely right not precisely wrong. The accuracy is sufficient to ensure that informed design decisions can be made by quantifying and comparing options. The conclusions drawn in this LCA are sensitive to the data sources and assumptions which should be understood carefully to ensure confidence in design decisions. Please contact eTool for clarification on the sensitivity of any conclusions drawn from this report.

List of Major References

ABARE, Energy in Australia 2009, Australian Bureau of Agriculture and Resources Economics, Australian Government, 2009.

Atech Group for Environment Australia, A National Approach to Waste Tyres, AustraliaCommenwealth Department of Environment, 2001.

Athena Institute, Minnesota Demolition Survey; Phase Two Report, Athena Institute, 2004,

D&R International LTD, 2009 Buildings Energy Data Book, US Department of Energy, Washington. 2009.

Department of Climate Change and Energy Efficiency, Your Home Technical Manual Fourth Edition, Department of Climate Change and Energy Efficiency, Australian Government, Canberra. 2010.

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Energy Use in the Provision and Consumption of Urban Water in Australia and New Zealand, CSIRO and Water Services Association of Australia, CSIRO, 2008.

Inventory of Carbon and Energy (ICE), Sustainable Energy Research Team, Department of Mechanical Engineering. University of Bath, UK. 2008.

NABERS Office Reverse Calculator v9.0, www.nabers.com.au

NSW Department of Environment and Climate Change, Sustainability in the Commercial Property Sector, 2009

US Energy Energy Information Administration, Annual Energy Outlook 2011, US Department of Environment & US Energy Information Administration, Washington. 2011.

The LCA predictions of embodied and operational impacts (including costs) conducted in eTool software, by their very nature, cannot be exact. It is not possible to track all the impacts associated with a product or service back through history, let alone do this accurately. The software has been built and tested to enable informed decision making process when comparing design options. Generic cost and environmental impact coefficients do not necessarily correspond to those of individual brands of the same product or service due to differences within industries in the way these products and services are delivered. eTool PTY LTD cannot make assurances regarding the accuracy of these reports for the above reasons.