LOW CARBON LIVING CRC

Sustainability Tools and Frameworks for High Performance Housing

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Executive Summary

Residential housing is a major contributor of greenhouse gas (GHG) emissions with most emissions being generated during the operation of buildings.

The housing sector is considered by many as presenting the most cost effective opportunities to reduce GHG emissions and the use of assessment tools and frameworks can assist in the guidance of design, implimentation and operation to improve buidling efficiency and performance to achieve this goal.

Currently there are two tools used in Australia for the mandatory assessment of energy efficiency in residential buildings at the design stage. The Nationwide House Energy Rating Scheme (NatHERS) is the most well-known, being mandatory in five out of six Australian States. The Building Sustainability Index (BASIX) replaces NatHERS in New South Wales (NSW) and the Australian Capital Territory (ACT).

Energy efficiency is clearly a key component in reducing household GHG emissions, however Life Cycle Assessments (LCA) that account for the carbon footprint across the life of the building should also be considered. Other characteristics such as accessibility, adaptability, and livability are all important in the context of improving the sustainability of residential buildings.

This Report provides an overview of NatHERS and Basix, as well introduces two emerging sustainability tools (eTool LCA and ARCActive[1]). A high performance housing Case Study is provided to demonstrate how these tools and framworks can be applied.

Figure 1: Appropriate building orientation, northern glazing and the use of high thermal mass (heavy) internal construction materials are important elements of this high performance, energy efficienct home (Photo credit: Joel Barbitta).

[1] At the time of publishing this report, ARCActive was in the process of rebranding as Living Key (www.livingkey.com.au).

1. Introduction

Buildings are responsible for 32% of the global energy use and generate the equivalent to 19% of energy related greenhouse gas (GHG) emissions (Lucon et al., 2014). Most emissions generated by buildings are indirect, that is they are produced during the operation of the building mainly through electricity usage. The International Panel for Climate Change (IPCC) estimates that if business as usual continues, the energy use in buildings will likely double or triple by 2050 (Lucon et al., 2014). Even though commercial buildings will see their energy consumption rise over the next thirty-five years, the main rise in final energy use will occur in the residential sector, which currently consumes nearly three times as much as the commercial sector (24.3 PWh and 8.42PWh respectively) (Lucon et al., 2014).

The scale of this may seem daunting, however the residential sector is considered by many as presenting the most cost effective opportunities to reduce greenhouse gas emissions (Levine et al., 2007; Ren et al., 2011). Technologies used to achieve low carbon and 'zero emission homes' (ZEHs) are proven and accessible. Studies have also demonstrated that ZEHs are affordable and can therefore be adopted as a minimum standard (Uihlein and Eder, 2010; Ürge-Vorsatz et al., 2012; Harvey, 2013; Moore, 2014). Indeed, policies towards zero emission housing have already been implemented in several jurisdictions, including the European Union, the state of California (USA) and the United Kingdom (Department for Communities and Local Government, 2006; European Comission, 2010; California Energy Commission, 2013). Other OECD countries such as Canada, Japan and Australia are also making efforts towards lowering residential emissions through minimum energy efficiency requirements in their building codes (IEA, 2008). Post-occupancy monitoring studies have confirmed that houses designed to be low emission perform better than conventional houses (Hamada et al., 2003; Berry et al., 2014). However, it has also been demonstrated that these houses do not reach their full potential, often presenting discrepancies between their design and operational energy consumption (Gill et al., 2010; Ambrose et al., 2013; Majcen et al., 2013; Ridley et al., 2014). Barriers impeding the optimal performance of low carbon houses are present at all levels, from design and evaluation (Lowe and Oreszczyn, 2008; Moore et al., 2014), to construction and verification (IEA, 2008) and house day-to-day operation (Gill et al., 2010; Bond, 2011).

Energy efficiency is clearly a key component in reducing household carbon emissions, but we need to go further. Life Cycle Assessments (LCA) that account for the carbon footprint across the life of the building, including materials should also be considered. Water usage also needs to be addressed, as well as other characteristics such as affordability, accessibility, adaptability and biodiversity which are all important in the context of lowering the impact of residential buildings (Maliene and Malys, 2009; VillarinhoRosa and Haddad, 2013).

This Report provides an overview of several rating tools and frameworks that can be used to evaluate the energy efficiency, carbon footprint and broader sustainability values of residential dwellings, from design, to operation.

The discussion focuses on the Australian setting. To begin with, mandatory housing energy assessment tools and their regulatory context are outlined, followed by the discussion of two emerging 'beyond compliance' tools that address Life Cycle Assessment, as well as broader sustainability outcomes. A case study showing how each of these has been applied to guide the design and assessment of a high peformance house in Fremantle, Western Australia is then provided.

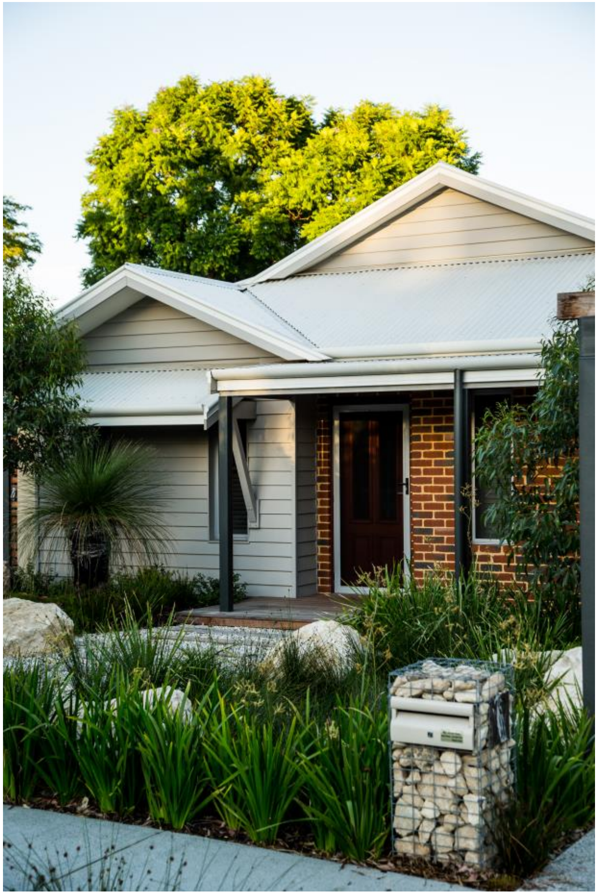

Figure 2: Landscaping is an important consideration in a sustainable home. Here low water use native plantings are used for stormwater management, increase local biodivesity and provide shade to the eastern side of the house (Photo credit: Morgan Gillham).

2. Assessment Tools and Frameworks

There are two tools used in Australia for the mandatory assessment of energy efficiency in residential buildings at the design stage. The Nationwide House Energy Rating Scheme (NatHERS) is the most well-known, being mandatory in five out of six Australian States. The Building Sustainability Index (BASIX) replaces NatHERS in New South Wales (NSW) and the Australian Capital Territory (ACT). There are also a number of voluntary, or 'beyond compliance' tools available that can be used at the design stage to assist with best practice sustainability outcomes, including the Green Buildings Council of Australia 'Green Star' and the Urban Development Institute of Australia 'EnviroDevelopment' certification programs, both of which are used for large-scale residential developments. eToolLCD and ARCActive Certified are emerging tools that can be used for both single and multi-residential properties. This content of this Report focuses on assessments used for single residential dwellings.

NatHERS

NatHERS was initiated in 1993 and formally introduced into the National Construction Code (NCC) (previously known as the Building Code of Australia (BCA) in January 2003 as a means of establishing a minimum energy efficiency requirement to maintain thermal comfort in dwellings. It's is based on a simulated thermal performance of the building design and incorporates factors such as climate zone, building area, orientation, insulation, building materials, thermal mass and glazing type (Department of Climate Change and Energy Efficiency, 2012).

Rating scores are given on a scale of 0-10, with the higher the star rating, the less the energy required to make a house thermally comfortable. Theoretically a 10-Star rated house should require very little or no artificial heating or cooling to be comfortable year round (Commonwealth of Australia, 2010) (see Table 1). When first introduced, new residential buildings and major alterations were required to meet a 4 Star rating. This has progressively increased to 5 and currently 6-Stars (The Department of Industry and Science, 2014).

Table 1: NatHERS Star Band Criteria (Energy Loads in MJ/m2.annum) for selected ratings in Australian Capital Cities (Adapted from Department of Climate Change and Energy Efficiency, 2012).

Location	Energy Rating (stars)			
	4	**5**	**6**	**10**
Darwin	480	446	349	119
Brisbane	71	55	43	10
Perth	118	89	70	4
Sydney	68	50	39	6
Melbourne	198	149	114	2

NatHERS accepts three different pieces of software for calculation of the thermal energy load in residential buildings including Accurate Sustainability, BERS (Building Energy Raing Scheme) Professional and FirstRate 5. Although these software products have been developed by different organisations and present different user interfaces, they all use the same calculation engine, developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO) (Department of Industry and Science, n.d.). The software is commercially available and can be used by anyone, however only accredited assessors who have undertaken recognised training through Association of Building Sustainability Assessors (ABSA) are able to provide a certified rating required to meet compliance under the NCC. A list of current accredited assessors can be found at www.absa.net.au.

One of the major limitations of NatHERS is that it does not provide an indication of the overall energy efficiency of a home, nor other measures of sustainability. Even though heating and cooling are typically responsible for the biggest residential energy demand (around 40%) (DEWHA, 2008), other major energy uses such as water heating, appliances and lighting are not considered. Likewise, other important resource efficiency factors that have significant environmental and carbon footprint implications such as the use of renewable energy, water efficiency, embodied energy and occupancy scenarios are not taken into consideration.

NatHERS has also been criticized for the lack of consistent results between assessors. In a recent benchmarking study, the CSIRO re-rated a number of houses and compared them to their original rating, revealing that nearly 50% of the houses had been rated higher than they were supposed to (Ambrose et al., 2013). Other limitations include poor construction practices leading to under performance of buildings when compared to the design rating, the lack of as-built verification and the increase of non-accredited assessors in the market place (Pitt&Sherry and Swinburne University of Technology, 2014).

Although NatHERS is the only framework recognized by the NCC in most Australian states, numerous other house assessment tools have been developed around Australia with the aim of complementing NatHERS and delivering a more comprehensive house sustainability evaluation.

BASIX

The Building Sustainability Index (BASIX) was developed by the Government of NSW in 2004 under the Environmental Planning and Assessment Act 1979. All new residential dwellings and major renovations costing more than $50 000 in NSW must comply with the BASIX targets. These targets consist of minimum performance levels for thermal comfort, water and energy. The targets are as follows (NSW Department of Planning & Environment, n.d.-a):

1. 40% reduction in potable water consumption based on the annual NSW average potable water consumption per capita (90,340 litres per capita per year);

2. 40% reduction in greenhouse gas emissions based on the annual NSW average residential energy consumption per capita (3292 kg of CO2-e per capita per year);

3. Thermal comfort targets are described in the BASIX Thermal Comfort Protocol (NSW Department of Planning & Environment, 2013), which establishes maximum heating and cooling loads for different construction types in each region of NSW (see Table 2).

The targets for water, energy and thermal consumption are calibrated for different regions, in accordance to regional environmental characteristics such as climate, precipitation, evaporation and soil type.

The BASIX assessment is web-based and free, which means that it can be used by anyone who registers on the BASIX website. Users are guided step-by-step through the assessment process and are required to input data about the development, which enables the software algorithm to anticipate water, energy and thermal performance of the building (NSW Department of Planning & Environment, n.d.-b). The user starts by inputting project details, which include the location of the project, the type of development and building areas. The next step is focused on water and consists of providing data about water supply, garden area, plant types and internal fixtures. The energy assessment requires information about types of heating and cooling devices, water heating method, ventilation systems, lighting systems and renewable energy.

Table 2: Maximum load for single dwellings in selected regions of NSW (Adapted from NSW Department of Planning & Environment, 2013).

	Heating (MJ/m2.annum)			Cooling (MJ/m2.annum)		
Region	**Slab on ground**	**Suspended floor, enclosed subfloor**	**Suspended floor, open subfloor/ mudbrick walls**	**Slab on ground**	**Suspended floor, enclosed subfloor**	**Suspended floor, open subfloor/ mudbrick walls**
Sydney CBD	40	43	46	32	35	38
East Sydney	51	58	63	45	49	53
West Sydney	74	82	80	70	77	83
Canberra	240	255	265	30	35	39

Three methods can be used for the thermal performance assessment section depending on the project complexity (NSW Department of Planning & Environment, n.d.-c). A ‘Do-It-Yourself’ method is a simplified assessment for single dwelling houses which use standard construction material. This method requires the user to input information about construction type, insulation, glazing and orientation. A ‘Rapid’ method enables single story detached dwellings to meet the target by complying with prescribed requirements. For the thermal assessment of complex designs, thermal loads need to be simulated by accredited assessors through one of the NatHERS accredited software. Both ABSA and the Building Designers Association of Victoria (BDAV) provide a database of accredited assessors that can be used for this purpose. A BASIX certificate can be obtained for a fee if all targets are met.

Post-occupancy monitoring studies have shown that BASIX-certified houses are successfully achieving their 40% water reduction target (Sydney Water, 2012; Hydrosphere Consulting, 2013). However, there is not enough data to support the performance of the other targets and indicate whether they are being met (Kahagalie and Mansfield, 2010; Tan, 2010).

eToolLCD

eToolLCD is an open-use web-based software tool applied to conduct life cycle assessment (LCA) of new buildings (commercial or residential) and all associated infrastructure. The software calculates the embodied energy of buildings and predicts the energy and water that will be consumed over the building lifespan as well as operational costs. eToolLCD can also measure environmental impacts such as greenhouse gas emissions, land use, ozone depletion and human toxicity (eTool, 2014a).

The following is taken into consideration by eToolLCD when calculating the embodied energy of a building (Haynes, 2010):

1. Initial embodied energy of materials, which is based on existing LCA databases;
2. The energy utilised for the transport of materials to the construction site;
3. Energy required for earthworks, onsite assembly and installations;
4. Recurring embodied energy due to maintenance and fit outs.

eToolLCD requires users to provide information about the type of materials used as well as quantities required (e.g. volume or weight). Embodied energy is then modelled based on existing LCA databases (Haynes, 2010). Transportation method, distance travelled, machinery and hours of equipment used can also be inputted by the user (Beattie et al., 2012). Materials that require maintenance or replacement during the lifetime of the building, such as wall painting and carpets, are taken into consideration and modelled by the software. Both embodied energy and transportation of these recurring materials are calculated in the model (Haynes, 2010). Existing templates are available for typical construction materials and methods and can be used by the user if required.

Operational energy is calculated based on the occupancy, appliances (e.g. refrigeration, lighting, water heating, thermal control), type of energy supply (e.g. grid, renewable energy system), mains water supply and sewerage treatment (Beattie et al., 2012).

eToolLCD allows for the generation of several different scenarios in order to compare design modifications and associated environmental impacts and costs. Once the LCA is complete and the most adequate design is selected, a report is created and a rating is given according to the building performance. Platinum is the highest available rating. In order to obtain a Platinum medal, a building must achieve more than 90% savings in greenhouse gas emissions (CO2-e) (measured against the standard building) in addition to receiving a gold medal for both operational and embodied carbon. Platinum is followed by Gold, Silver and Bronze, which require savings of 60-90%, 30-60% and 30% respectively (eTool, 2015b). Even though the software can be used for free, certifications can only be obtained after verification by the eTool team and payment of a subscription.

Since its development in Western Australia in 2010, eToolLCD has developed over 200 building LCAs and has reached countries such as the United Kingdom, Germany and Brazil (eTool, 2015a). eToolLCD is currently being used for the conduction of EN15978 LCA compliant studies and is also adopted as a component of other building assessments, including Green Star and EnviroDevelopment (eTool, 2014b).

While eToolLCD has been very successful modelling greenhouse gas emissions of buildings around the world, the many variables and assumptions made by the software make it difficult to predict the performance of a building accurately, even though examples of post-occupancy monitoring studies show that buildings modelled by eToolLCD are achieving expected outcomes (Bruce, 2013; Byrne, 2014).

ARCActive Certified

ARCActive Certified (to be rebranded as Living Key: www.livingkey.com.au) is an emerging tool developed by ARCActive. It consists of a multi-criteria assessment designed to evaluate the overall sustainability of a property. This tool takes into consideration not only the building envelope and its usage, but also the adaptability of the dwelling, its location to key services, its connectivity and the quality of life that it provides to its inhabitants. The following categories are analysed by ARCActive: Energy, Water, Liveability, Resources, Nature, Community and Transport. Unlike the tools presented beforehand, ARCActive is unable to predict greenhouse gas emissions or forecast water and energy consumption in a building. Instead, it attributes points for sustainable initiatives, design and community integration, making it an 'easy to understand' rating system. When evaluating the 'Energy' category, points are given for houses with a high NatHERS rating. It also takes into consideration solar passive design, renewable energy generation, water heating, method for climate conditioning and fit outs. The 'Water' category assesses water sourcing and reuse (e.g. rainwater, greywater, groundwater), in-house fixtures, plant type and irrigation methods. The 'Liveability' category addresses quality of life, assessing features such as universal access, low allergen features and gardens (e.g. on-site food production, compost and appropriate shading). The objective of the 'Resource' category is to evaluate building adaptability, longevity and embodied energy. Points are allocated to the usage of recycled materials. The 'Nature' category supports and promotes native vegetation as well as biodiversity, both in the property and in the vicinity. The objective of the 'Community' category is to assess services available at a reasonable distance to the property in order to foster walkability and community interaction. Finally the 'Transport' category checks the quality and proximity to public transport, which is important for greenhouse gas reduction and can help to reduce the cost of living. .

The house assessment is conducted by an accredited assessor who completes the evaluation for each of the mentioned categories, rated in a scale from zero to ten. The summary average of all assessments is named 'ECOnomics' and provides the rating of the overall property sustainability. A report provides suggestions to improve the dwelling sustainability.

Although ARCActive is a new rating system, it has assessed some of the leading high performance homes around Australia, including NatHERS 10-Star Josh's House (Beyer, 2012), NatHERS 8-Star CSIRO Australian Zero Emission House (Beyer, 2014a) and NatHERS 8-Star CSR House (Beyer, 2014b), complementing the mandatory NatHERS thermal energy efficiency evaluation.

The table below (Table 3) provides a summary of the rating tools discussed in this report

Table 3: Summary of selected residential rating tools utilised in Australia.

Rating tools	Criteria assessed	Applicability	Coverage
NatHERS	• Thermal energy load	• Residential dwellings	• National • Mandatory
BASIX	• Water • Thermal comfort • Greenhouse gas emissions from energy consumption	• Single house and Multi-Unit • Alterations and Additions above $50 000	• New South Wales • ACT • Mandatory
eToolLCD	Life Cycle Analysis: • Embodied carbon • Operational carbon • Overall greenhouse gas emissions • Cost • Water usage • Energy usage • Toxicity • Ozone depletion • Land usage • Eutrophication • Acidification	• Residential • Commercial • Development • Infrastructure	• Voluntary
ARCActive Certified	• Energy • Water • Liveability • Resources • Nature • Community • Transport	• Single or multi-residential properties	• Voluntary

3. Case Study: Josh House

Background

Josh's House is an innovative housing project in the suburb of Hilton, Western Australia, which aims to demonstrate that high performance energy efficient homes can be built at comparable cost and timeframes to regular houses.

The project consists of two dwellings which were designed to provide thermal comfort year round, without the need for air conditioning or additional heating. They are self-sufficient in electricity and they harvest and recycle water. In addition to private garden areas, a productive garden supplies both houses with fresh food.

What distinguishes this project from many others is that the building designs have achieved a 10 Star energy efficiency rating (refer Attachment 1), whilst intentionally using conventional building materials and construction methods so they can easily be replicated by the industry and the wider community. The project also demonstrates a more sensitive approach to residential subdivision that has considered maximising effective garden area around the homes to allow for natural shading, children's play spaces and local food production.

This following setion describes the design and sustainability features of the two homes and explains how they achieved not only a high energy efficiency rating certification, but also excellence in sustainability, while remaining economically affordable and appealing to the general public. A summary of the the eToolLCD and ArcActive Certified assessments is also provided.

Design Features

The floor plans of the two dwellings are typical of many family homes. There is however key points differentiating Josh's House from other family homes, such as carefully considered building orientation, strategic use of thermal mass and improved insulation. Consideration has also been given to product choice and natural ventilation for good indoor air quality, as well as universal access design. The houses are largley self-reliant in electricity, they harvest rainwater and reuse greywater for garden irrigation. These sustainability features are explained in further detail below.

Thermal Comfort

The houses are based on well-established solar passive design principles to ensure maximum thermal comfort year round, with no air-conditioning or artificial heating required.

The property where the homes were built was chosen due to its ideal orientation for climate sensible design. Measuring around 60m by 20m on an east-west axis, the block was subdivided in a typical 'battle axe' arrangement to provide two building sites which maximise the potential for northern solar access. The orientation of the houses, window location and internal layout has been done on the basis of maximisng the solar passive performance. The key solar passive design principles employed include:

- East-west orientation with maximum glazing to the north for winter solar gain (shaded in summer) and minimal glazing to the east and west to minimise summer heat entry.
- High thermal mass materials used on the inside of the buildings to absorb winter solar gain and stabilise internal temperature during summer.
- High insulation value to roof and walls to minimise uncontrolled heat loss/gain, and pelmets curtains on the windows to reduce heat loss in winter.

The external walls are a combination of reverse brick veneer, double brick and lightweight timber framing. Reverse brick veneer and double brick walling was been used in order to increase internal thermal mass where it was needed. Where this was not required, timber framed walling was used due to its lower embodied energy value and therefore, lower carbon footprint. All external walls are insulated with a combination of bulk insulation and closed cell foil insulation. Internal walls are plastered single leaf brickwork with some double brick walls used to add additional thermal mass to the main living areas, as well as sound insulation to selected rooms.

Low-e glazing was chosen throughout to regulate heat flow. Only one double glazed window was required in each house to achieve a 10 Star rating and this was in the kitchen where the use of curtains to reduce winter heat loss was not practical. In other living areas double line drapes with pelmets were used to act as window insulation.

The roof is conventional timber construction with light coloured reflective roof sheeting with insulated foil underneath. The ceiling is lined with bulk insulation to achieve an R4.0 insulation value. The northern living areas feature a decorative concrete slab finish to store the heat from the winter sunlight and to help stabilize internal temperature during summer.

Energy Efficiency

Energy efficient fixtures and appliances, combined with onsite power generation also contribute to the high energy performance of the houses.

Lighting is provided by a combination of LED lights in the bedrooms and living areas, and compact fluorescent globes in occasional use areas. Reversible ceiling fans are also installed in the bedrooms and living areas to provide downward cooling and upward circulation of warm air in winter.

Each house has a 3kW grid connected photovoltaic system installed which were sized to generate more power than required to run the homes, as well as gas boosted solar hot water systems. Solar tubes help to 'daylight' internal areas such as walk-in robes to reduce the need for artificial lighting during the day.

Indoor Air Quality

In order to ensure a good indoor air quality, materials with low Volatile Organic Compounds (VOCs) were used for cabinetry, paint and floor finishes. Protection from termite attack is in place through physical termite barriers as opposed to chemical treatment systems. There are no skirting boards and the window pelmets are 'hidden' to reduce dust collecting surfaces.

Universal Access

The houses are on one level, have a minimum doorway width of 870mm for wheel chair clearance, as well as flush thresholds to all external doors, hobbless showers and general circulation space in the rooms.

Water Efficiency

High efficiency shower heads and tap ware have been selected, and the low volume dual flush toilets have integrated hand basins which use tap water to fill the cistern.

Both houses have direct diversion greywater systems to provide irrigation to selected areas in the garden, as well as rainwater tanks for internal usage, with mains water back up for dry periods. The productive garden is watered from a shared bore and state of the art centrally controlled irrigation system, incorporating both soil moisture monitoring and weather monitoring to maximise water efficiency.

Landscaping

The landscaping also help address a number of pressing urban sustainability issues including improved household energy efficiency through appropriate shading, habitat provision with local native plantings, as well as local food production with an extensive shared vegetable garden, home orchard, poultry and composting and worm farm system.

The hard landscaping works incorporate locally sourced and salvaged materials. Permeable surfaces have been used throughout to allow for localised storm water infiltration.

Both houses have been designed to have north facing gardens adjacent to the open planned living areas. Large 28 course high sliding glass doors with flush thresholds open on to an extensive decked area, shaded by grape vine clad pergolas and strategically placed shade sails, providing a seamless transition between inside and outdoor living.

The required street frontage setback for the front house is dedicated to native plantings in a contemporary style that includes a fire pit, and stone wall seating for small gatherings. There is 'dampland' habitat feature planted with local 'winter-wet depression' suited species, fed by rainfall runoff from the carport.

A common garden between the two houses functions as a shared space, simply by not having a boundary fence. Features in this area include a large productive garden (vegetables, herbs and fruits), a propagation area and access to a hen house for collecting eggs. The elements in this space have been set out so that if a boundary fence is installed at a later date, then each property will still have access to their own respective vegetable beds, garden shed and composting facilities.

A 25m fruit tree system runs along the northern face of the southern boundary fence line, and was planted with a combination stone fruit, apple and pear varieties. Larger fruit trees including citrus, fig and guava have been incorporated into mixed edible landscapes around the houses. Spaces have also been set aside for creative children's play, outdoor cooking and entertaining, as well as private courtyards by the master bedrooms.

Assessment Results

Josh's House has achieved 'Exceptional' rating under the ARCActive categories 'Energy', 'Water' and 'Liveability' (refer Atachment 2). The ARCActive assessment describes the project as "an outstanding example and excellent model for sustainable living in the suburban context (Beyer, 2012)".

eTool (2012) estimated that the two Josh's House dwellings will use less than 10% of the total energy used in typical Australian new homes (Figure 3), saving an average $2000 per year in energy costs, at current prices. The Global Warming Potential Impact of the homes was estimated at 420 kgCO2e per year per occupant, which represents a 90% decrease in greenhouse gas emissions compared to the typical business as usual design. In regards to water, it was estimated that Josh's House will use around 40% of the scheme water of a typical Perth home, whilst still supporting a diverse and productive garden (Figure 4). The eToolLCA report for Josh's House is provided as Attachment 3.

When comparing the total cost of Josh's House to a typical 'new Perth home' in terms of construction, energy and maintenance over time, it was found that Josh's new home is much more affordable than the average Australian house. The construction cost is slightly higher upfront, however, the payback period is only seven years, due to reduced operating and maintenance cost. From year 7 onwards, the benefits get much larger over time. It is predicted that by year 25, Josh's House cumulative cost will have been on average 20% lower than the traditional home costs (Figure 5).

The NatHERS and life-cycle assessment undertaken for Josh's House shows that the buildings can be classified as both high performance thermally, as well as ZEH. But more than that, Josh's House is an exemplar of a holistic approach to this type of residential dwelling, that considers a multi-criteria approach to sustainable design rather than simply thermal performance and energy efficiency in isolation.

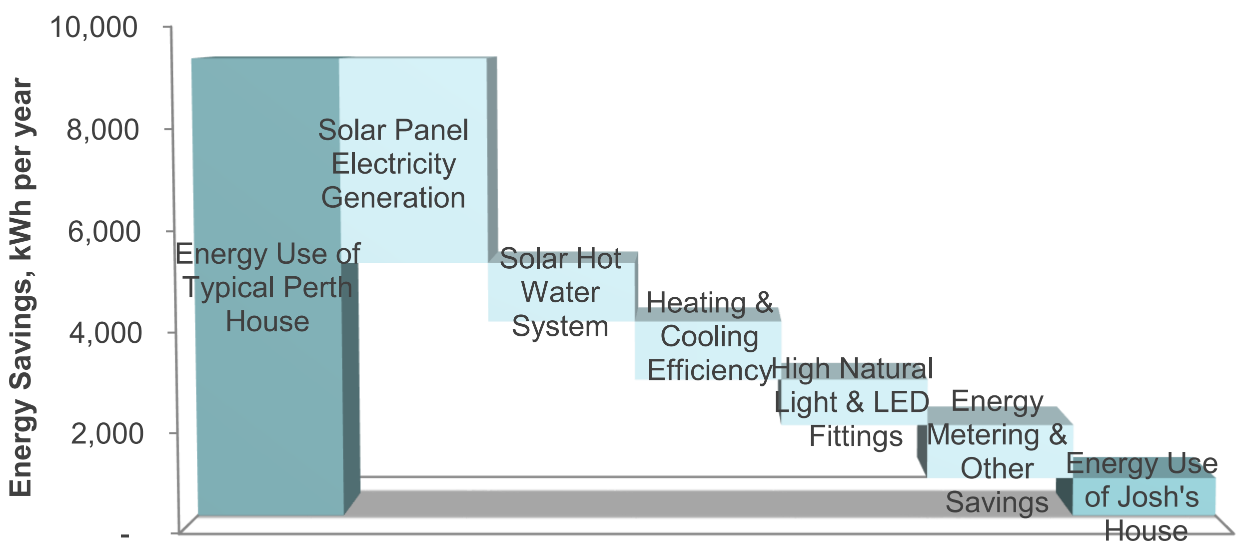

Figure 3: Modelled energy use for Josh's House using eToolLCA.

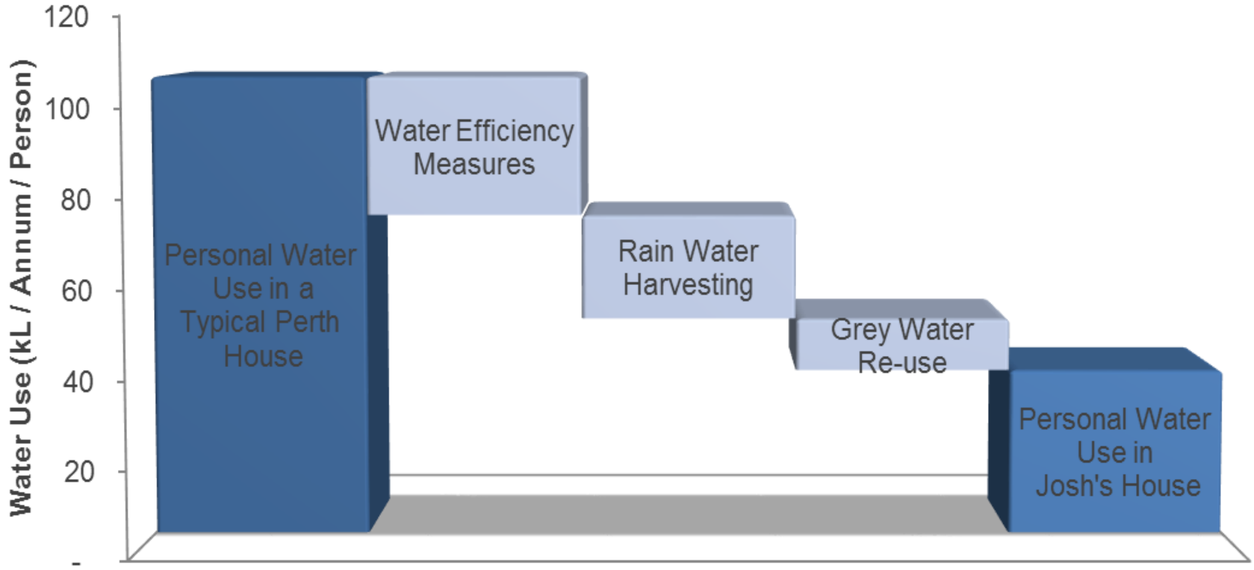

Figure 4: Modelled water use for Josh's House using eToolLCA.

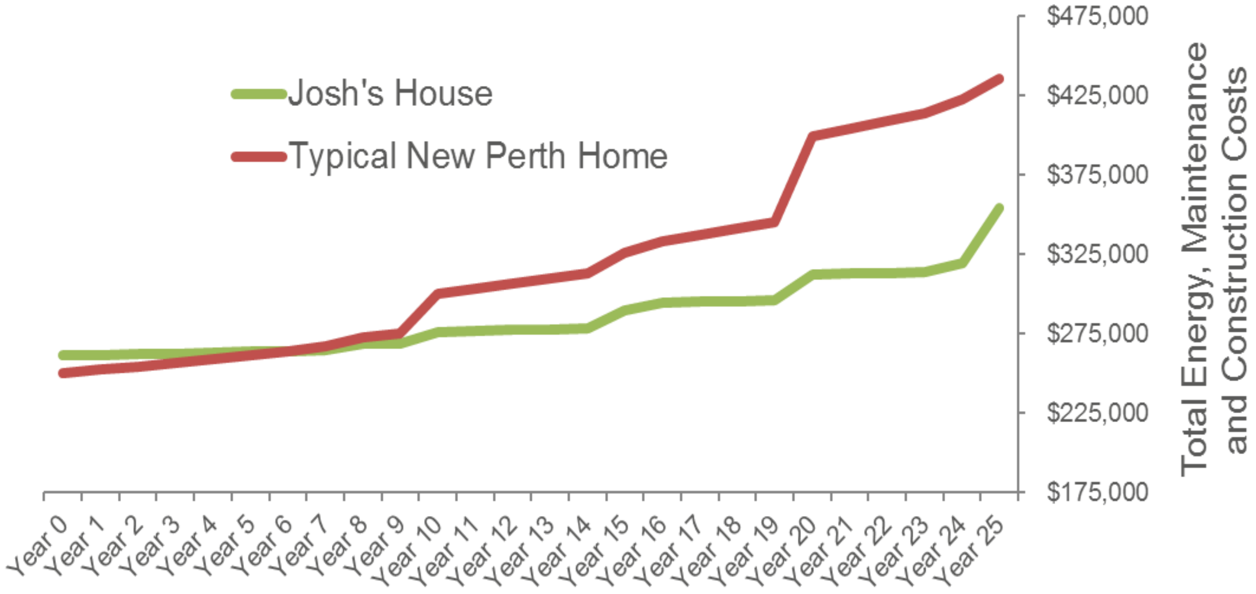

Figure 5: Modelled life cycle cost comparison for Josh's House using eToolLCA.

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Appendix

1. Josh's House NatHERS Certificate
2. Josh House ArcActive Certified Report
3. Josh's House eToolLCD Report

Assessor Certificate

Single Dwelling

Certificate Version 6.1.1. Prior versions not valid after 1 March 2006

Issued in Accordance with the requirements of

BCA P3.12 0.1 - Class 1 and 10a only (State variations apply)

Assessor

Name: Natalie Scott **Company** Ecostar Consulting Assr #: 60316

Address: PO Box 2246 Mandurah WA 6210

Phone 0411 44 93 44 **Fax:** **Email:** info@ecostarconsulting.com.au

Declaration of interest: None

Client

Name: Griff Morris **Company:** Solar Dwellings

Address: 23 Green Street Mt Hawthorn WA 6016

Phone: 08 9444 4400 **Fax** 08 9444 4600 **Email:** griff@solardwellings.com.au

Project

Address: 2/ 19 Grigg Place HILTON WA 6163

Lot / DP: 1499 / 6339 **LGA:** Fremantle City Council

Applicant: Griff Morris

Assessment

Date: 18/09/2012 **Job ID:** 374 **Filename:** Byrne_Maher U2 Lot1499 **Run #** 1

Software: BERS **Version:** 110811 **Climate Zone:** 52

Referenced documents

All details upon which this Assessment has been based, are included in the project documentation which has been stamped and signed by the Assessor issuing this Certificate, as detailed below:

Thermal Performance Specification / Commitments attached and affixed to drawings, page Cover

Drawings: Byrne & Maher - Unit 2 SSL 2 of Lot 1499 Grigg Place, Hilton

Specifications: HH12008 Rev 3 28/08/2 Sheets 1-15

ABSA Assessor Certificate **Assessor # 60316** **Certificate #46895358** **Issued:21/09/2012**

BCA P3.12.0.1 - Building envelope thermal perfomance assessment

Area calculations (M2)

Net Conditioned Floor Area 122 **Net Unconditioned Floor Area** 35

Predicted annual energy loads (MJ/M2/year)

Heating 1 | **Cooling (sensible plus latent):** 1 | **Total:** 2

Dwelling Area Adjustment (MJ/M2/year)

Area Adjusted Total 2

Rating

★★★★★★★★★★

10.0 stars

ABSA Assessor stamp

ABSA

Assr# 60316 Cert# 46895358

Sign N. Scott.

Date 21/09/12

ABSA Ltd. Level 9 Elizabeth Towers 418A Elizabeth St Surry Hills NSW 2010

phone: 1300 889 438 fax: (02) 9281 9514 email: admin@absa.net.au www.absa.net.au

ABSA Assessor Certificate	Assessor # 60316	Certificate # 46895358	Issued: 21-Sep-2012

Thermal Performance Specifications Thermal Performance Specifications BCA P3.12.0.1. (State variations apply)

These are the Specifications upon which the Certified Assessment is based. If details included in these Specifications vary from other drawings or written specifications, these Specifications shall take precedence. If only one specification option is detailed for a building element, that specification must apply to all instances of that element for the project. If alternate specifications are detailed for a building element, the location and extent of alternate specifications must be detailed below and / or clearly indicated on referenced documents.

Windows	*Product ID*	*Glass*	*Frame*	*U value*	*SHGC*	*Area M2*	*Detail*
Generic		Single Low E	Aluminium	4.70	0.63	41.2	Throughout
Generic		Double Glazed	Aluminium	4.27	0.67	1.6	Kitchen (south)

Skylights	*Product ID*	*Glass*	*Frame*	*U value*	*SHGC*	*Area M2*	*Detail*
Generic		Custom	Tubular			0.12	Master Bed WIR

Any U and SHGC values specified on Certificates Issued after 1 May 2007 are according to NFRC. All values prior to this date are ANAC.
Alternate products may be used if their U value is lower, and the SHGC value is less than 10% higher or lower

External Walls	*Construction*	*Insulation*	*Colour = Solar absorptancy*	*Detail*
Cavity Brick - Rendered		"Permicav"	Medium - SA 0.475 - 0.7	As per plans
Cavity Brick - Face Brick		"Permicav"	Medium - SA 0.475 - 0.7	As per plans
Reverse Brick Veneer		"Permicav" + R2 Batts	Medium - SA 0.475 - 0.7	As per plans
Stud Frame		"Permicav" + R2 Batts	Medium - SA 0.475 - 0.7	As per plans

Internal Walls	*Construction*	*Insulation*	*Detail*
Single Brick		None	As per plans
Double Brick		None	As per plans
Stud Frame		None	As per plans

Floors	*Construction*	*Insulation*	*Covering*	*Detail*
Concrete SOG		None	Bare	Kit/Dine/Fam & Activity
Concrete SOG		None	Timber	Bedrooms & Hall
Concrete SOG		None	Tiles	Wet Areas

Ceilings	*Construction*	*Insulation*	*Detail*
Plasterboard		R4 Batts	Throughout

Roofs	*Construction*	*Insulation*	*Colour = Solar absorptancy*	*Detail*
Metal		Anticon R1.5	Light -SA <0.475	Throughout

Window Covers	*Internal (curtains)*	*External (awnings, shutters, etc)*
None	Throughout	None

Fixed Shadings	*Eaves (width - inc gutters, height above windows*		*Verandahs,Pergolas (type, description)*	
	0	0 Varies as per plans	Timber & Shade Sail	Act & Dine/Fam (north)

Overshadowing	*Overshadowing structures*	*Overshadowing trees*

Orientation, Exposure, Ventilation and Infiltration	
Orientation of nominal north elevation	0
Terrain category	Suburban
Roof Ventilation	Ventilated <2% of area
Cross Ventilation	Standard
Subfloor Ventilation	On ground
Living area open to entry:	No
Living areas separated by doors:	Yes
Stair open to heated areas:	No
Seals to windows and doors:	Yes
Exhaust fans without dampers:	No
Ventilated skylights:	No
Open fire or unflued gas heater:	No
Vented downlights:	No
Wall and ceiling vents:	No

ABSA Assessor Stamp

ABSA
Assr# 60316 Cert# 46895358
Sign N. Scott.
Date 21/09/12

ARCACTIVE

ARCACTIVE PLACE CERTIFIED

Property Report

Grigg Place Project

SUSTAINABILITY • LIVEABILITY • CERTIFICATION

The key to Sustainable Living

ARCACTIVE PLACE CERTIFIED

PROPERTY REPORT

Grigg Place Project

Project Name:	**Grigg Place Project**
Address:	**Grigg Place, Hilton WA 6163**
Client:	**Josh Byrne**
Assessment Date:	**1 December 2012**

ARCACTIVE PLACE CERTIFIED
COMMENDABLE
ECONOMICS

EXCEPTIONAL — ENERGY

EXCEPTIONAL — WATER

EXCEPTIONAL — LIVEABILITY

MATERIALS

NATURE

COMMENDABLE — COMMUNITY

COMMENDABLE — TRANSPORT

ARC ACTIVE
SUSTAINABILITY • LIVEABILITY • CERTIFICATION

PROPERTY REPORT
Grigg Place Project

This property is an outstanding example and excellent model for sustainable living in the suburban context.

It has achieved a very high rating under the ABODE Rating - Energy, Water, Liveability and Materials.

The dwellings 10 star thermal performance rating and optimal climate responsive 'passive solar' design, as well as renewable energy systems ensures it achieve very high performance levels for Energy.

Similarly for Water: large volume rainwater harvesting with extensive uses in the home and for garden irrigation and greywater reuse, smart irrigation systems, native and water sensitive plants and best practice design in productive gardens ensure it also excels.

In the Materials category it has met the fundamentals of long-life flexible design and incorporates durable low maintenance and good use of recycled/reused materials.

For Liveability and Healthy Living it has excelled across all key criteria which include passive solar design, universal access, low allergen and abundant vegetation ensuring the occupants are living in and contributing to a healthy environment.

The CONNECT Rating (Nature, Community and Transport) has achieved a reasonable outcome.

For Nature, the combination of careful selection and placement of local native and water sensitive plants on the lot and some reasonable native vegetation in street verges and open space support achieving a better than average result.

It achieved a Commendable rating under Community due to its close proximity to shops, services and schools, and that this suburb has an active and engaged community focus.

For Transport it also achieved a Commendable rating: the property is within the accepted walkable catchment of 400 meters to two bus routes, however the location lacks the high-frequency public transport routes required to achieve a higher rating.

David Beyer

Technical Director
ARCACTIVE

PROPERTY REPORT
Grigg Place Project

Category Rating	Score	ABODE (85%) - Notable Attributes
EXCEPTIONAL ENERGY	94%	10 Star Energy Efficiency Rating – requiring no mechanical heating or cooling systems Excellence in Climate Responsive 'Solar Passive' Design Renewable energy systems - 3kw PV, and Solar/gas HWS High efficiency fixtures and appliances Real time data monitoring
EXCEPTIONAL WATER	96%	20,000 litre Rainwater tank – supplying all internal fixtures and appliances (with mains water back-up Integrated greywater system irrigating selected gardens areas Waterwise native and productive gardens High efficiency fixtures and appliances
EXCEPTIONAL LIVEABILITY	98%	Climate responsive design – providing natural light, ventilation Universal Access providing safe and accessible access High Indoor Environment Quality though natural ventilation and low allergen materials Native and productive gardens and shade trees
MATERIALS	56%	Compact dwelling on infill block in an inner/suburban location Durable, low maintenance materials Recycled materials – timber reuse for decking, pergola and garden structures
		CONNECT (72%) - Notable Attributes
NATURE	67%	Extensive native plant species within lot and front verge Street trees in local nieghbourhood Local proximity to local parks with significant trees
COMMENDABLE COMMUNITY	74%	Close proximity to all key community facilities - local shops, day care, pre, primary and high schools, medical facilities and parks. Hilton is also an active community with a community garden, community centers and local cafes, shops and small businesses.
COMMENDABLE TRANSPORT	75%	Good proximity – within the accepted 400m walkable catchment - to two local bus routes Good connection to pedestrian and cycle paths
		ECOnomics - Summary Result
COMMENDABLE ECONOMICS	80%	Best practice in climate responsive and environmental sustainable design achieves a Very Good status with the Adobe categories. The Exceptional rating for Energy and Water ensure this property is very economical to run. The Connect rating reflect the suburban local. It is a suburb with a good community focus and amenity, has quality nature throughout, but is average in accessibilty to public transport.

ARCACTIVE Star Ratings and Percentage Scores:
1 Star = 0-10%; 2 Stars = 11-20%; 3 Stars = 21-30%; 4 Stars = 31-40%; 5 Stars = 41-50%;
6 Stars = 51-60%; 7 Stars = 61-70%; 8 Stars = 71-80%; 9 Stars = 81-90%; 10 Stars = 91-100%;

PROPERTY REPORT

Grigg Place Project

ARCACTIVE PLACE CERTIFIED

ABOUT ARCACTIVE

ARCACTIVE is a suite of rating tools, services and resources for industry and consumers to assess and certify the liveability and sustainability of properties. Its core objective is to address the market need for an easy to understand 'rating assessment' of the key liveability and sustainability features and attributes of new or existing properties.

ARCACTIVE Assessment Categories

ARCACTIVE PLACE CERTIFIED	This is the full ARCACTIVE rating and certification to demonstrate the full liveability and sustainability attributes of the property
ARCACTIVE ABODE CERTIFIED	ARCACTIVE rating and certification of categories relevant to building performance only. (Must be completed with a current HERS report)
ARCACTIVE CONNECT CERTIFIED	ARCACTIVE rating and certification of categories relevant to community, nature, transport connections and location only

ARCACTIVE Categories and Descriptions

ENERGY	WATER	MATERIALS	LIVEABILITY	NATURE	TRANSPORT	COMMUNITY
Design features and fixtures of the property that optimise good design and conserve and produce energy	Design features of the garden, and fixtures and appliances that conserve and re-use water	Well located and long life buildings with low energy content and are from sustainable sources	Design features, materials and finishes, and location, which enhance human and environmental health	Type, amount and diversity of vegetation on the lot, on street verges and in open space, and proximity to bushland	Proximity of the property to public transport, walking and cycling paths, and bicycle storage	Proximity of the property to local amenities and services such as shops, schools, day care, community centres and parks

ECONOMICS	Summary average of ALL assessment categories to indicate the ECOnomic benefits and potential of the property

http://www.arcactive.com.au/

ARC ACTIVE
SUSTAINABILITY • LIVEABILITY • CERTIFICATION

eTool Life Cycle Assessment

Josh Byrne Residence
Grigg Place, Hilton, Western Australia

eTool PTY LTD
40-44 Pier St Perth
Western Australia
+61 8 6364 3805
info@etool.net.au

Josh Byrne Residence
Grigg Place, Hilton, Western Australia

eTool® CERTIFIED

A Life Cycle Assessment has been carried out on the proposed design, calculating the carbon emissions due to materials' manufacture, materials' transport, building construction, maintenance and operations. The boundary of the assessment includes the foundations, floors, walls, roof, internal finish, external finish, services and basic fittings. The results measured against a benchmark are summarized below:

Building Embodied Carbon:
757 kgCO_2e per year per occupant. Saving of 23%

eTool BRONZE

Building Operational Carbon
-342 kgCO_2e per year per occupant. Saving of 111%

eTool PLATINUM

Total Building
420 kgCO_2e per year per occupant. Saving of 90%

Assessed by Henrique Mendonca

Certified by Richard Haynes

4th December 2012

The Ratings Explained:

- Bronze Medal: 0 - 30% Carbon equivalent greenhouse gas emissions (CO_2e) saving against the applicable benchmark
- Silver Medal: 30 - 60% CO_2e saving
- Gold Medal: 60 - 90% CO_2e saving
- Platinum Medal: More than 90% CO_2e saving. Gold must be achieved in all categories for an overall Platinum rating.

Life Cycle Assessment: Josh Byrne - Base Design

Executive Summary

In order to quantify and improve the design of the Strata Lot 2 - Rear a life cycle assessment (LCA) has been conducted. Three LCAs were conducted, each representing an alternative design:

- A business as usual or benchmark design, "Strata Lot 2 - Rear Brick Veneer, BCA Climate Zone 5, Perth NEW"
- Base case design, "Strata Lot 2 - Rear Josh Byrne - Base Design"
- Improved design with modeled recommendations, "Strata Lot 2 - Rear Josh Byrne - eTool recommendations"

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 "Strata Lot 2 - Rear Josh Byrne - Base Design" is 65 years whilst the maximum durability is 175 years.

The Global Warming Potential impact associated with the base case design totalled 68,693 kgCO2e

Taking into account the functional units of the building, this is equivalent to 408 kgCO2e/year/occupant. This represents a 90% or 3,684 kgCO2e/year/occupant saving compared to the benchmark.

With recommendations a saving of 118% or 4,826 kgCO2e/year/occupant can be achieved.

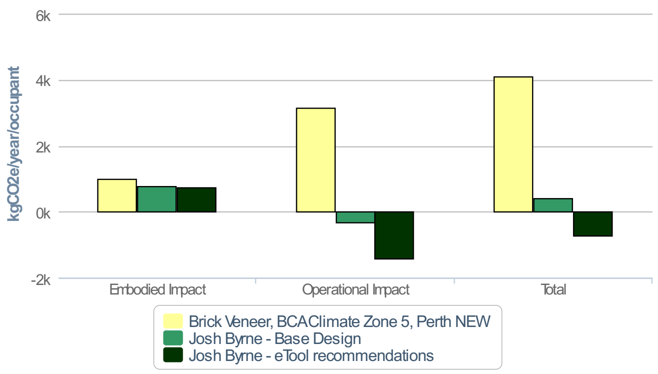
Having quantified the impacts associated with the base case design, this enabled a number of recommended design improvements to be identified. These are summarized below:

- Customised ventilation for fridge can save up to 15% on energy consumption and represents a total of 9.2t CO2e over the life of the building.
- Use of natural gas for oven represents a total savings of 5.9t CO2e over the life of the building.
- Increase solar PV system to 3.5kW capacity to achieve full carbon neutral, saving a total of 101.7t CO2e over the life of the building.
- The following recommendations have also been provided for consideration on future projects where more flexibility exists to change the functionality of the buildings:
  - Increase design life through future proofing. Further design options that would enable to 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. (not modelled in the design)
  - Increase design life through higher density. Increase the density of the building to reduce the embodied emissions. By increasing density, the expected design life of the dwelling would increase. This is due to it becoming a less unattractive target for redevelopment than lower density surrounding buildings. Shared walls also mean half the embodied impacts per dwelling for the wall. (not modelled in the design)
  - Better utilisation of materials through increased ability to de-construct. Use materials that can be de-constructed 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). Not modelled in the design
- Previous to this LCA report, the following lower embodied energy recommendations were made but not progressed due to the project requirements to build with readily accessible and available products and methods :
  - Reduce internal finishes with exposed brick on internal walls will save a total of 3.2t CO2e over the life of the building.
  - Use of 50% fly ash concrete will save 3.2t CO2e over the life of the building.
  - Use of recycled bricks represents a saving of 3.1t CO2e over the life of building.
  - Rammed Earth Floors throughout - 10t CO2e daving (assumed 200mm slab thickness)
  - Straw Bale External Wall Construction - 10t CO2e saving
  - Timber window frames throughout - 2t CO2e saving
  - Recycled timber to framed wall elements - 1.3t CO2e saving
  - Recycled timber to roof structure - 1.2t CO2e saving

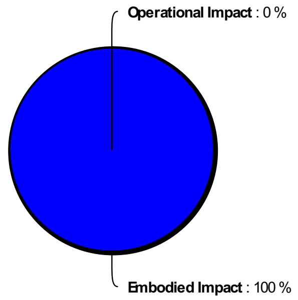
The following charts provide some further information regarding the comparative impacts of the three designs. A comparison has also been provided of the largest embodied and operational impacts. The detailed percentage split of impacts sources relating to the base case design have also been provided.

Total Life Cycle Global Warming Potential

Comparison of Global Warming Potential Profiles:

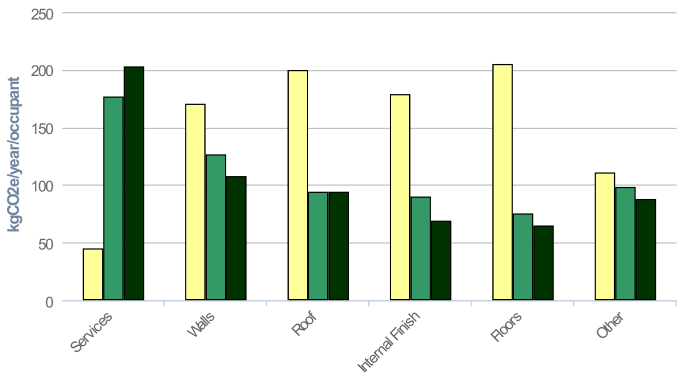


Total Global Warming Potential Profile for Josh Byrne - Base Design

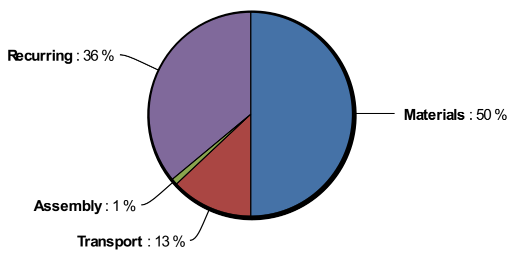


Embodied Global Warming Potential

Comparison of Embodied Global Warming Potential:

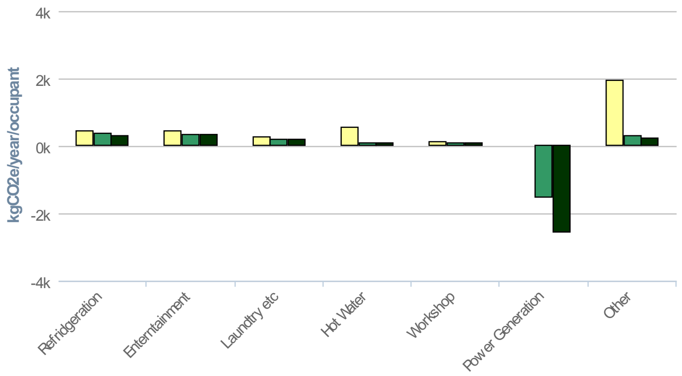


Embodied Global Warming Potential Profile for Josh Byrne - Base Design

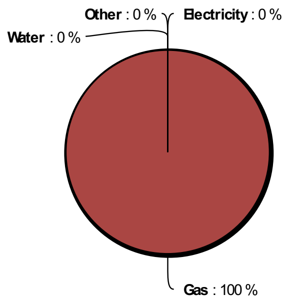


Operational Global Warming Potential

Comparison of Operational Global Warming Potential:



Operational Global Warming Potential Profile for Josh Byrne - 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.

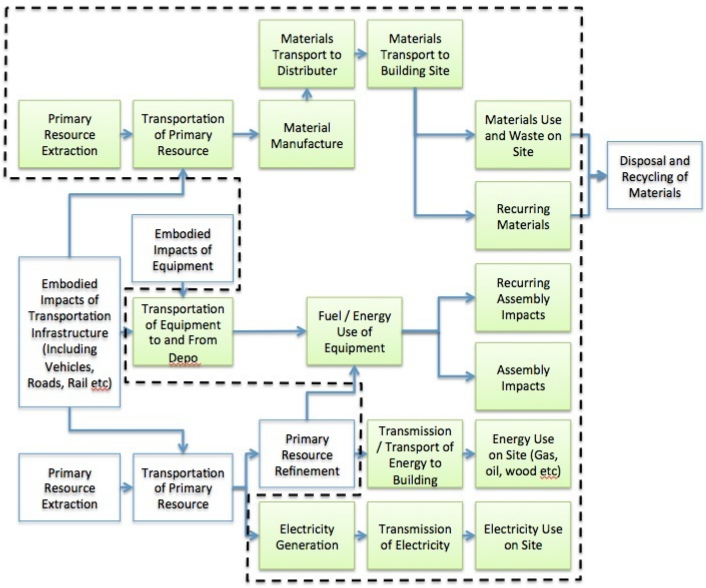


Figure 1: System Boundary of LCA

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:

- Josh Byrne - Base Design: 68,693 kgCO2e
- Brick Veneer, BCA Climate Zone 5, Perth NEW: 339,689 kgCO2e
- Josh Byrne - eTool recommendations: -123435 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 "Strata Lot 2 - Rear Josh Byrne - Base Design" is 65 years whilst the maximum durability is 175 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

- Customised ventilation for fridge can save up to 15% on energy consumption and represents a total of 9.2t CO2e over the life of the building.
- Use of natural gas for oven represents a total savings of 5.9t CO2e over the life of the building.
- Increase solar PV system to 3.5kW capacity to achieve full carbon neutral, saving a total of 101.7t CO2e over the life of the building.
- The following recommendations have also been provided for consideration on future projects where more flexibility exists to change the functionality of the buildings:
  - Increase design life through future proofing. Further design options that would enable to 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. (not modelled in the design)
  - Increase design life through higher density. Increase the density of the building to reduce the embodied emissions. By increasing density, the expected design life of the dwelling would increase. This is due to it becoming a less unattractive target for redevelopment than lower density surrounding buildings. Shared walls also mean half the embodied impacts per dwelling for the wall. (not modelled in the design)
  - Better utilisation of materials through increased ability to de-construct. Use materials that can be de-constructed 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). Not modelled in the design
- Previous to this LCA report, the following lower embodied energy recommendations were made but not progressed due to the project requirements to build with readily accessible and available products and methods :
  - Reduce internal finishes with exposed brick on internal walls will save a total of 3.2t CO2e over the life of the building.
  - Use of 50% fly ash concrete will save 3.2t CO2e over the life of the building.
  - Use of recycled bricks represents a saving of 3.1t CO2e over the life of building.
  - Rammed Earth Floors throughout - 10t CO2e daving (assumed 200mm slab thickness)
  - Straw Bale External Wall Construction - 10t CO2e saving
  - Timber window frames throughout - 2t CO2e saving
  - Recycled timber to framed wall elements - 1.3t CO2e saving
  - Recycled timber to roof structure - 1.2t CO2e saving

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

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