Project management framework for delivering sustainable residential developments

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Project Management Framework for Delivering Sustainable Residential Developments

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THESIS CERTIFICATION

I, Scott Redwood, declare that this thesis, submitted in fulfilment of the requirements of the award of Master of Engineering by Research in the School of Civil, Mining and Environmental Engineering, Faculty of Engineering, University of Wollongong, is my own work unless otherwise acknowledged. The document has not been submitted for qualifications at any other academic institution.

Scott Redwood

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ABSTRACT

Sustainable residential development is the pursuit of increasing house liveability through form, function, materials, operation and comfort, while reducing the overall environmental impact of the development with marginal increases in capital cost. The ability to successfully design and construct sustainable residential developments is important, as the housing sector in Australia accounts for a large and escalating share of the nation's energy consumption. Achieving any significant reduction is greatly dependent on the knowledge and skill of the design consultant and engaged builder. It is generally accepted that only a minority of practitioners in the industry are experienced in the subject area of sustainable residential development, and that there is a significant amount of work to do in improving standard design and building practices, processes and decision making in Australia. Accordingly, this research focussed on the development of a standardised project management approach to successful delivery of sustainable residential developments.

The objective of this research was to develop a project management framework to assist design and construction professionals in delivering sustainable houses. To develop the framework, case studies on current sustainable residential developments and project management best practices are presented. Interviews with key stakeholders in the Australian market (i.e. clients, design consultants and building contractors) are also presented and discussed. The author interviewed four clients, one architect, one building designers and two builders. Key findings included the importance of deriving and monitoring sustainable project objectives (derived from social, financial and environmental indicators), stakeholder management, information dissemination and communication, and facilitated decision making with respect to managing outcomes. To validate the project management framework the framework was applied to two practical case studies.

The case study results show that specific focus on the project management of sustainable residential developments can reduce the environmental impact of the development by up to 90% over its life-time, with an increase in capital cost of between 5.1% and 6.2%. Furthermore, the design can reduce operating demands by up to 50% in energy and up to 80% in water, while maintaining more comfortable internal living conditions.

The research outcomes confirm that sustainable houses can be achieved through management practices, and with a relatively low increase in capital cost. The application of the project

management framework allowed project decisions to optimally align and balance the project objectives. During each case study better outcomes could have been achieved for each specific project objective, however, this may have led to compromises being made on other project objectives. To deliver truly sustainable houses all stakeholders must go beyond objective segregation and impromptu implementation, and utilise a management framework to balance the delivery of a tailored and comprehensive list of sustainable objectives, with successful design and construction outcomes.

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LIST OF ABBREVIATIONS

DCP	Development Control Plan
LEP	Local Environmental Plan
BCA	Building Code of Australia
NCC	National Construction Code
AS	Australian Standard
DA	Development Application
CC	Construction Certificate
PM	Project Management
HR	Human Resource
KPI	Key Performance Indicator
IPG	Initiating Process Group
CSF	Critical Success Factors
NRB	National Residential Benchmark
ESD	Environmental Sustainable Design
DSS	Decision Support System
MCDA	Multi-Criteria Decision Anaylsis

CHAPTER 1. INTRODUCTION

1.1 Introduction

Sustainability is a broad and complex concept that is most evident in the construction industry. Balancing the essential, but in some cases conflicting, objectives of sustainability will, in principle, lead to building developments that are environmentally and socially sustainable without compromising their economic feasibility. The present research project is based on the premise that, in order to achieve sustainable developments, a holistic and tailored approach to project management and decision-making for building projects is required. Currently, there is a great deal of research related to this domain, but obstacles still stand in the way of their integration into current project management processes. This thesis therefore aims to develop a project management framework that more effectively delivers sustainable objectives through the management of the decision-making process in the early stages of residential building designs. This chapter outlines the research background, aim and objectives, research methodology and the structure of this thesis.

1.1.1 Research Background

The increase in human populations and the standards of living in countries around the world have highlighted our built environment as a major threat to our natural environment (Akadiri, 2011), and in some instances our social prosperity (Sarkis *et al.*, 2011). The economics and operation of our built environment, the natural environment and our society are undoubtedly linked, through the three themes of sustainability: economic, social and environmental sustainability (Madu and Kuei, 2012, Sarkis *et al.*, 2011). In recent years the relationship between the three themes of sustainability have gained unprecedented exposure, which has driven an increase in government action towards progressively tightening environmental compliance in building standards, and scientific research into how best to deliver balanced sustainable building developments (Sarkis *et al.*, 2011). As understanding and awareness of the impacts of building developments grows, increasing efforts are being made to reduce or avoid adverse effects, generally through a targeted approach at one specific stage or action within the supply chain for building developments. Life-Cycle Assessment (LCA) is now seen as a widely accepted method to measure the total impact of our built environment, and

therefore measure effectiveness of the targeted efforts to reduce this impact. The value and validity of the LCA method has instigated a change in the current sustainable rating tool approaches, with early stage adoptions of LCA method into their frameworks (Fava, 2006).

Currently, LCA is too complex and time-intensive for widespread application, nevertheless it provides fundamental insights into environmental impacts of building developments and a tool for validations (Cole, 1998). Sustainable rating tools have attempted to bridge the gap between demonstrated sustainable best practices, and integrating sustainable best practice into developments by providing a structured framework (Ding, 2008). Regardless of their limitations, this has allowed environmental rating tools to gain recognition and widespread adoption by governments and private investors (Ding, 2008). Environmental rating tools only prescribe measures of 'environmental sustainability', and not a methodology for the management of high-level sustainability objectives and the large number of interconnected decisions that need to be made in any building development.

1.1.2 Research Aim and Objectives

The aim of this research was to define and develop a project management framework that will aid in the successful delivery of future residential building developments by balancing the objectives associated with each of the three themes of sustainability. The project management framework will help to ensure that design and construction outcomes of future projects are a result of precise management of the projects' sustainability objectives. The framework will encompass the entire design and construction stage and will be applicable to residential developments.

The research objectives were to:

- Investigate sustainable residential building development;
- Determine key project management considerations for successful implementation of building projects;
- Investigate sustainability awareness of architects, designers and builders and how it influences their management of projects and decision-making;
- Develop a project management framework for delivering successful sustainable developments;

- Validate the developed project management framework through case studies.

1.1.3 Research Methodology

This research project included a study of the strategic approach taken by key stakeholders to implement sustainability into their building developments, and how it influenced their management and decision-making. It focuses on the management and decision-making processes during the project from the concept design stage to final completion (handover of the building to the 'owner'). This study required a comprehensive evaluation of sustainable residential development best practices, current decision-making techniques and project management methodologies and integration. The implementation of sustainable practices in the construction industry is investigated via the use of interviews with professionals and clients, and reviewing past solar decathlon entrants. It is then examined alongside current literature into the delivery, through decision-making, of key sustainable development objectives. In addition, the influence project management practices have on the delivery of sustainable development objectives is examined. Coupled with action research, a sustainable residential project management framework was then developed. Finally, the project management framework was implemented on two residential developments. The evaluation of the framework was gauged by comparing the sustainable project objectives against the design and construction outcomes. The tools used for evaluation were energy modelling (DesignBuilder), life-cycle analysis (eTools), water analysis, and cost planning and construction tendering.

1.1.4 Thesis Structure

This thesis is comprised of eight chapters, and Figure 1 outlines the relationship of each chapter towards the overall thesis program.

Chapter 2 contains a comprehensive review of relevant literature in the area of sustainable development, and current methods, frameworks and techniques used to design, construct and validate sustainability within the built environment. The Solar Decathlon competition is a core focus of this chapter.

Whilst Chapter 2 focuses on the broader discussion relating to sustainable development, Chapter 3 focuses on the theory of project management and its relevance to construction management. This chapter examines current project management best practices, and published case studies that focus on achieving sustainable development objectives, either directly or indirectly using project management and/or decision-making practices.

Chapter 4 explains various research methodologies, outlining their strengths and weaknesses. Each selected research methodology is referenced back to the aim and objectives of this thesis. In addition, this chapter reviews current environmental rating systems that were used to evaluate the implementation of the project management framework.

Chapter 5 reviews the Australian building development industry in terms of building performance, cost, current design and building practices, and application of 'sustainability' within the market. In addition, this chapter presents interview results which had a focus on sustainability awareness and real-world application for the domestic client, designers/architects and builders.

Chapter 6 presents the conceptualised Sustainable Residential Development Project Management Framework that has been developed. With reference to previous chapters, the framework contextualises the interconnected nature of sustainable development, and how this can be managed during the life of a sustainable residential development.

Chapter 7 presents two sustainable residential development case studies that demonstrate the application of the project management framework. The case studies represent typical Australian scopes, requirements and budgets. The validation of the framework is discussed in terms of application and the achievements of the sustainable development objectives.

Chapter 8 summarises the research findings, states the conclusions, and provides recommendations for future research.

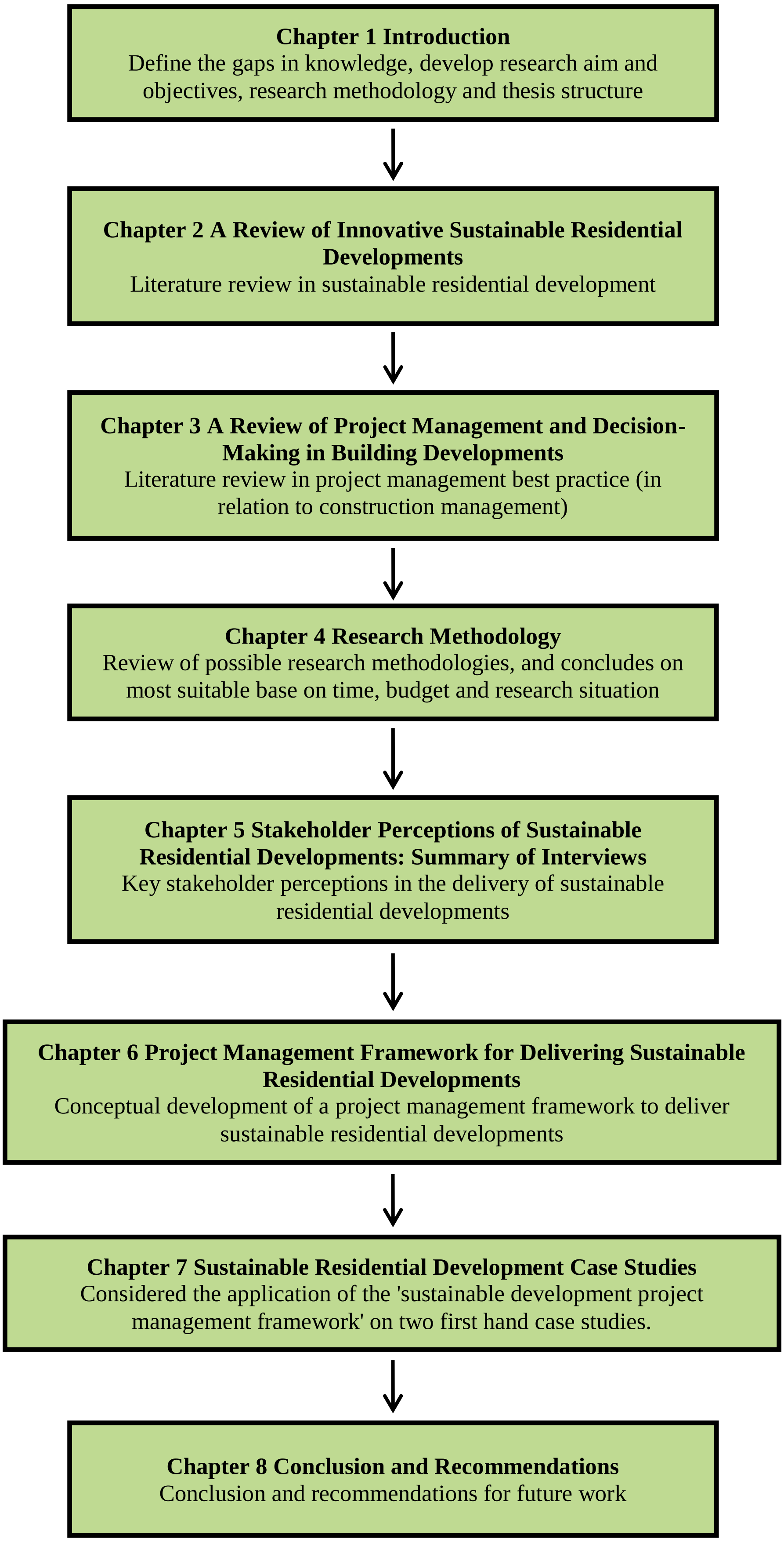

Figure 1: Thesis Structure

CHAPTER 2. A REVIEW OF INNOVATIVE SUSTAINABLE RESIDENTIAL DEVELOPMENTS

2.1 Introduction

The aim of this chapter is to gain a greater understanding of what sustainable development means and how it is defined, implemented and measured. This requires a review of the literature and case studies concerning sustainable design and construction frameworks. A critical review of their level of success, failure and degrees of effectiveness for delivering pre-defined sustainable objectives is presented.

The chapter begins by discussing the context around 'sustainable developments', and how it is perceived and implemented in the present day. Also outlined are key sustainable objectives for benchmarking overall design and implementation with respect to sustainable residential developments. The chapter then presents a review of solar decathlon case studies, outlining key challenges that confronted their design and construction. It concludes by addressing the chapter objectives that are outlined in Table 1.

Table 1: Chapter 2 Research Objectives

OBJECTIVES	TASK
	Review related research in the field.
	Review the historical context of sustainable developments, from inception to its evolution to current practices.
Investigate sustainable development implementation	Determine key sustainable development objectives for benchmarking residential houses.
	Review of current sustainable rating tools used to evaluate the environmental impacts of design and construction of buildings.
	Review the Solar Decathlon competition.

2.2 Sustainable Development

The generally accepted meaning of the term 'sustainable development' comes from a publication by Brundtland (1987) – "development which meets the needs of the present without compromising the ability for future generations to meet their own needs". This single quote has aligned much debate about what sustainable development embodies and represents, which led to the development and acceptance of the three themes of sustainability – the 'Triple Bottom Line': economic; environmental; and social (McCarthy and Rasekh, 2013). However the most effective means to achieve the meaning is still largely debated in

government, research and industry circles, and consequently they are separated and varied in their approaches. This can largely be attributed to the relative importance placed on each sustainable objective, and therefore the perspective of the given government body, research area, and industry type. This research has a focus on delivering sustainable building developments, through an integrated design and management approach (from development concept to operation), and more specifically residential homes - to do this, key sustainable development objectives are required. Development objectives provide any development with a purpose - the reason for their existence - and a means to measure their success and failure (PMI, 2008). Aligning development objectives with the three themes of sustainability will favourably evolve all facets of design and construction industry to ever more sustainable outcomes (Zhang and London, 2011, Mills and Glass, 2009, Dair and Williams, 2006). To achieve sustainable outcomes, the building industry has adopted sustainable rating tools into their developments (Cole, 1998). The building industry has taken a hold of the sustainable rating tool approach through its tangible nature of measure and implementation into - as an 'add-on' - the standing project management processes (Zhang and London, 2011).

The relative success of any development is focused around the delivery of pre-defined project objectives, and therefore a direct connection can be made between the development objectives, project management processes for their delivery and the ability to obtain a sustainable result. Before this research can focus on the delivery of this sustainable result through the design development stage and project management practices, sustainable objectives and a 'sustainable result', and what factors influence their derivation, must be defined.

2.2.1 Themes of Sustainability: Triple Bottom Line

As discussed, the three themes for the triple bottom line best represent the broad meaning of the term 'sustainable development'. The focus of sustainability generally refers to only environmental factors, and refining and enhancing specific environmental outcomes, e.g. energy efficiency, carbon emission, recycling, and the like. However, for a development to be 'truly' sustainable, a marriage and a constant process of dynamic balance must exist between the three themes (Akadiri, 2011) (McCarthy and Rasekh, 2013) – refer to Figure 2.

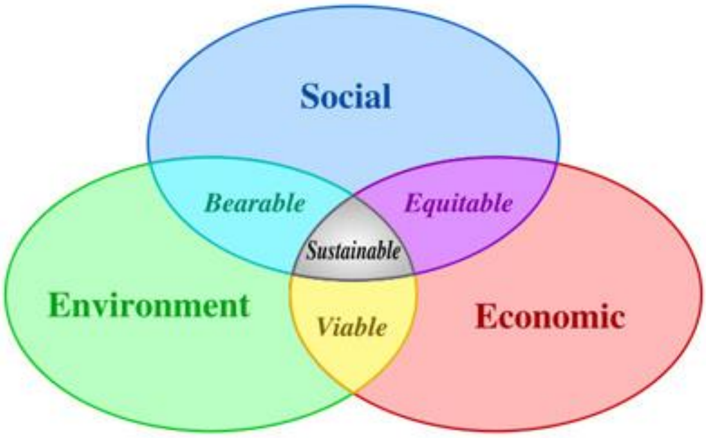

Figure 2: Triple Bottom Line

Traditionally, each of the three themes of sustainability has been considered as discrete areas of research focus, and subsets of focus, without practical consideration towards the sum of the whole. This approach instils levels of assumptions, boundaries and conditions to emulate the working environment of sum of the whole. Delivering building developments in practice requires information regarding each theme of sustainability, to achieve desired project outcomes. Combining all current practices, across all themes of sustainability is required to achieve an optimised result in sustainability for a building development (Zhang and London, 2011). Sarkis *et al.* (2011) argue the social aspect of sustainability is rarely considered, yet it holds the greatest influence in delivering sustainable outcomes. The key to delivering an optimised sustainable building development begins with deriving achievable sustainable project objectives (Zhang and London, 2011). Key sustainable indicators are effective in deriving achievable sustainable project objectives (Zhang and London, 2011, Sarkis et al., 2011). Key sustainable indicators and their connectivity and multidimensional nature are vital in commissioning sustainable developments, developing our knowledge and achieving our aim to measure and benchmark sustainable development outcomes.

Sarkis *et al.* (2011) developed a matrix of key economic, environmental and social indicators that should be considered within the built environment context. The sustainable indicators are expressed in Table 2, and attempt to holistically provide measures of sustainability for comprehensive evaluations for decision makers and benchmarking purposes. This publication does not diagrammatically express the connection of each theme of indicator, but expresses

the importance for balance, and ‘trade-off’ between each indicator through decision-making (Sarkis *et al.*, 2011).

Table 2: Exemplary Sustainable Indicators (Sarkis et al., 2011).

Economic/Business	Environmental	Social
Quality	Sustainable sites	Employment stability
Time	Water efficiency	Employment practices
Flexibility	Energy and atmosphere	Health and safety
Cost	Materials and resources	Capacity development
NPV	Indoor environmental quality	Human capital
ROI	Innovation and design process	Productive capital
		Community capital
		Information provision
		Stakeholder influence

Zhang and London (2011) conducted a similar evaluation and developed another set of key sustainable development indicators - refer to Figure 3. Zhang and London (2011) attempted to demonstrate the connectivity of the indicators across the three themes as well as the business process they influence. This means the business processes are directly related to the key indicators and the three themes of sustainability.

In comparison of the two arrays of sustainable indicators, the key indicators are closely aligned across the three themes of sustainability. However, it is felt that the full potential of the sustainable development indicators is not yet realised. The indicators can be used to guide sustainable development objectives, and therefore provide the key guidelines needed to facilitate rounded decision-making decisions to deliver the optimised development outcome - thus directing a sustainable development in the correct direction before ‘setting-sail’.

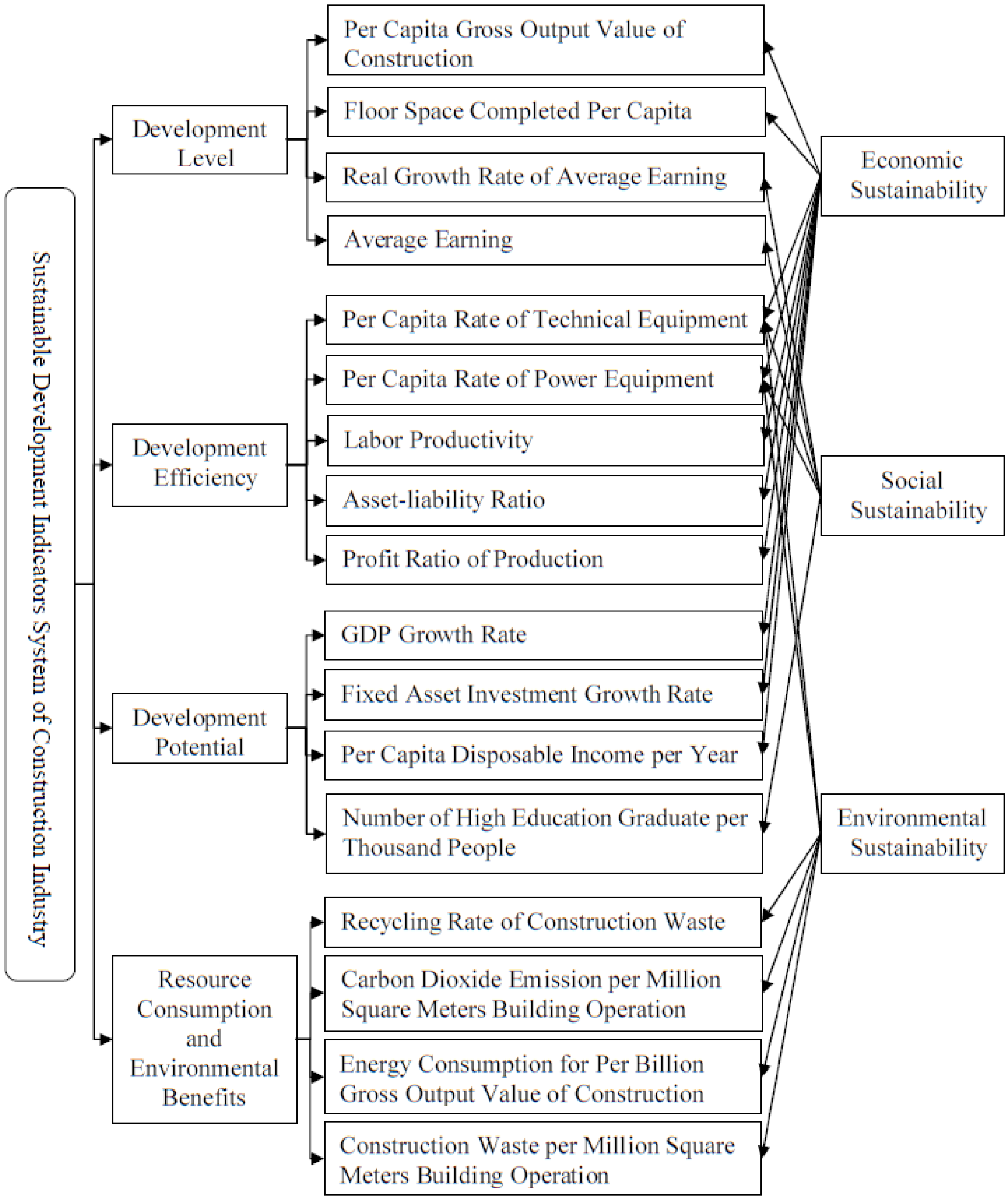

Figure 3: Connectivity between the Three Themes of Sustainability in the Building Industry (Zhang and London, 2011)

2.3 Sustainable Objectives

The objectives of a development are very important, they define the key deliverables and guide project management processes and decisions (Robichaud and Anantatmula, 2010). Robichaud and Anantatmula (2010) explained that the traditional project management methods are inherently linear and rely on a string of fragmented practices - which lead to significant rework as the building project becomes more complex. Therefore the traditional management practices are evermore ineffective to deliver the more technically complex

sustainable buildings. In order to deliver sustainable developments, the key stakeholders must elicit sustainable objectives at the on-set, and develop the project management framework that will empower the design decision-making process (Robichaud and Anantatmula, 2010). In addition, sustainable objectives will allow measuring project success and failures and the development of benchmarks. Objectives are typically derived from two main areas, firstly the requirements that stem from the feasibility studies and secondly aligning the objectives with the core business goals.

The conception stage or initiation stage of a building development is where the key stakeholders must define the developments sustainable objectives, as it is one of the major steps in the projects life cycle. As it has the largest influence by project sponsors and key stakeholders (PMI, 2008). This directly impacts, the yet-to-be defined and approved development objectives (Akadiri, 2011).

Dair and Williams (2006) argued that sustainable development objectives instil flexibility to choose and apply specific sustainability measures, tailored specifically to each development. Also, Dair and Williams (2006) described the importance of separating the defined objectives into the three themes of sustainability, as this will help identify implementation conflicts and trade-off solutions between the sustainable development objectives for stakeholders.

As discussed previously, sustainable development objectives can most successfully be developed with the support of sustainable indicators. Dair and Williams (2006) research followed a similar approach, utilising the sustainable indicators issued within UK government policy (DETR, 1999b). The indicators are:

1. Social progress which recognises the needs of everyone;
2. Effective protection of the environment;
3. Prudent use of natural resources; and
4. Maintenance of high and stable levels of economic growth and employment.

The above is not as advanced as the indicators illustrated previously, but assists the process in the same method. The final objectives developed by Dair and Williams (2006) were developed with respect to the development of five brownfield sites, the sustainable objectives are described in Table 3.

Table 3: Sustainability Objectives (Amended: Dair and Williams, 2006)

Themes of Sustainability	**Sustainability Objectives**
Economic Objectives	To enable business to be efficient and competitive
	To support local business diversity
	To provide employment opportunities
Social Objectives	To adhere to ethical trading standards and fairness-at-work policies
	To provide adequate local services and facilities to serve the development
	To provide housing to meet needs
	To integrate the development within the locality
	To conserve local culture and heritage, if appropriate
Environmental Objectives	To minimise the use of resources
	To minimise pollution
	Protect biodiversity and the natural environment

Dair and Williams (2006) described the situation where five developments were successfully implemented by using sustainable objectives, derived from sustainable indicators. Developing the sustainable objectives should be completed with the client and the key project stakeholders (project manager and the lead building designer) before any design and construction commences (Robichaud and Anantatmula, 2010). Ascertaining a comprehensive breakdown of sustainable indicators for sustainable Australian residential developments is a critical link in developing effective sustainable objectives for project clients and key stakeholders.

2.4 A Review of the Solar Decathlon Competition

The Solar Decathlon competition was created by the U.S Department of Energy, with their first competition taking place in Washington D.C. in 2002. The competition is a bi-annual, international competition where university students compete to design, build, transport,

operate and test energy-efficient, net-zero homes (Wallpe et al., 2012, U.S. Department of Energy, 2012). A net-zero energy home produces more energy annually then it consumes. The purpose of the Solar Decathlon is to (U.S. Department of Energy, 2012):

- *Educates students and the public about the money-saving opportunities and environmental benefits presented by clean-energy products and design solutions*
- *Demonstrates to the public the comfort and affordability of homes that combine energy-efficient construction and appliances with renewable energy systems available today*
- *Provides participating students with unique training that prepares them to enter our nation's clean-energy workforce.*

As the name implies, the competition comprises of 10 equally-weighted contests, with each being worth 100 possible points (1000 total points available). The 10 contests are comprised of both quantitative and qualitative (judged) evaluations. The contests are (U.S. Department of Energy, 2012):

- Qualitative:
    - Architecture
    - Market Appeal
    - Engineering
    - Communications
    - Affordability
- Quantitative:
    - Comfort Zone
    - Hot Water
    - Appliances
    - Home Entertainment
    - Energy Balance

Solar Decathlon competitions have been held in Europe and China, and the first competition in South America will be held in Colombia in December 2015.

2.4.1 Solar Decathlon case studies

The following case studies present technical achievements, lessons learnt and management strategies used by each team to deliver their entrants. A finding was initially evident between the teams, their approach and focus were dependent on their educational background. Architectural based teams had a greater focus on the building form and the building materials used, and 'simply' specified PV and HVAC systems. Whereas engineering proponent teams typically created a 'simple' building form with less emphasis placed on material impacts, only on material performances. In addition, the engineering team placed a high level of emphasis on solar generation and building system efficiencies (e.g. BMS, lighting and HVAC).

2.4.1.1 Gable House - The University of Illinois (Dhople et al., 2010)

The Gable House (GH) was an entrant by the University of Illinois (UI) into the 2009 Solar Decathlon in Washington D.C. The UI team wanted to maintain the ideals of sustainability beyond the competition rulings, by recycling and reclaiming and sourcing local materials - although the focus by the team, and this research paper was predominately engineering based. The GH has a traditional 'Midwestern vernacular'.

The Gable House received second place overall in the competition. The team won first place in home entertainment, appliances, and hot water, while placing second in net-energy consumption, indoor comfort and lighting design.

The UI Team was an engineering based team, and therefore it was noticed that a specific focus was placed on solar generation, power monitoring system, home automation and HVAC performance. The design of the GH electrical system revolved around energy efficiency, across all connected systems (including solar generation) and appliances. They employed a 9kW solar system, and which was monitored by the buildings BMS. The HVAC system was custom designed and operated, and could be operated in four modes: heating, cooling, max-cooling and off. The BMS logic controlled which mode the HVAC should be operating within depended on various temperature and humidity sensors.

The UI Team developed a house that was technically innovative in its engineering systems, and systems integration. What was not apparent was a connection between engineering

excellence and the other factors involved in designing and constructing sustainable houses. There was no indication that passive design, thermal performance or glazing were considered or implemented to achieving the competition targets, however a note was made that the GH aimed at achieving a PassivHaus air-tightness standard (Passive House Institute, 2012). In addition, there was no reference to how the house was managed to achieve their goals. Except that the goals for the team did not extend past achieving the 10 criteria set by the competition.

It is highly likely that if a greater emphasis was placed on the qualitative competition objectives (e.g. architecture, target market, etc..) and their integration with technical system requirements, a higher result would have been achieved.

2.4.1.2 Natural Fusion - Penn State University (Witmer and Brownson, 2010)

Penn State University entered to 2009 Solar Decathlon with their 'Natural Fusion' (NF) house. The NF house focused their concept on delivering a "...holistic integration of elements, bringing nature into the living space." (Witmer and Brownson, 2010). The NF house is Penn State's second solar decathlon entrant, with their first in the 2007 competition. From their lessons learn, the team ensured that the design process was integrative and iterative.

The NF house was developed using a cost-benefit analysis, to holistically review each element in the development of the design and construction. This helped the team make many numerous decisions over the 2-year project. In addition, the team staged the design over 5 increments: brain storm/charrette; identify attributes inherent in each design option; particularly with respect to changes in related aspects of the home design; cost-benefit analysis; develop a full design of the best option; repeat these steps if necessary. During the design development and benefits analysis, the team also used systems and energy modelling software as an additional decision-making criteria. Therefore, the engineering systems were integrated in the holistic, architectural and passive design of the home.

With this approach, and the team relying on their strict process of design evaluation - using a cost-benefit analysis, in some circumstances the team needed to make compromises to reach their optimum potential. The NF house received 16th place in the competition, but this is not

felt to be a negative toward their final product - a house that is as sustainable as the means to create it. This house, the team and their constraints are representative of the challenges faced by the 'mass' implementation of sustainability in the residential marketplace. The approach taken by the team lends itself to more investigation, to understand in more detail the disconnection between their initial goals, and the final house results.

2.4.1.3 Re_Home - The University of Illinois (Cady et al., 2012)

The Re_Home was the second entrant into the solar decathlon by UI Team - The University of Illinois. The Re_Home took part in the 2011 solar decathlon in Washington D.C. The concept of the Re_Home is to be easily and quickly deployable to disaster relief communities.

Like the Gable House, the Re_Home focused their efforts on solar generation, power monitoring system, home automation and HVAC performance. Through a high level of building efficiency, the Re_Home was able to maintain a net-energy position with only a 6.69kW combined PV system (1kW less than the average team system size). Overall the Re_Home placed 7th place in the competition, and placed first place in energy balance and appliances categories.

Most of the teams' points were lost because they did not adequately consider the qualitative competition requirements, and only focused on the performance of their engineered systems.

2.4.1.4 Magic BOX - Universidad Politecnica de Madrid (UPM) (Caamaño-Martín et al., 2005)

The "Magic BOX" was a creation by the Universidad Politecnica de Madrid (UPM) for the 2005 Solar Decathlon Competition in Washington D.C. The UPM Team wanted the Magic BOX to be more than a house that best achieve rigid and semi-rigid competition criteria; they wanted the house to ensure the home would give a greater quality of life by ensuring environmentally sensitive materials, minimised waste production and create an architectural form that encouraged indoor-outdoor spaces. The team also wanted to reflect, as accurately as possible, the demand of this home with typical U.S dwellings by purchasing the most common appliances throughout.

The Magic BOX is comprised of a structural steel frame (only required for transport and fast erection time - for the competition) clad in clay tiles. The predominant insulation used is wool-fibre, and the window frames are made from 100% recycled aluminium. The roof of the Magic Box is most impressive, with the use of a PV green-house (like) green roof. The efficiency of the semi-transparent PV panels over the green roof is less efficient than typical, but they can provide a more habitat-able green roof grown environment.

The Magic BOX consists of several innovative applications of building materials, technologies and systems. Although from this research paper, there seemed to be a lack in their integration. The team was approximately 60% architecture students and 40% engineering students; in addition there were three sub-teams. The sub-teams were:

- Architecture: Bioclimatic design, material selection, and construction.
- Energy Systems: Electrical supply, monitoring and supervision, and hot water supply
- Domestics: Domestic appliances, electrical and mechanical systems.

The architecture team discusses the use of bioclimatic design, to optimise solar angles at different times of day and different days of the year. The engineering team seems to operate on their own assumptions in developing their systems. There was no reference to the HVAC system and how the architectural building form would effective heating, cooling and dehumidifying loads.

2.4.2 The Illawarra Flame House - The University of Wollongong. A First Persons Perspective by the Teams Design and Construction Manager

Team UOW entered their Illawarra Flame house into the 2013 Solar Decathlon China competition in Datong. Team UOW decided to take a unique approach to their house concept, by being the first team in the history of the competition to demonstrate how to retrofit an existing home, into a sustainable-low carbon footprint-high performing home. They focused their philosophy around the core of the U.S. Department of Energy's and the China National Energy Administration's premise, to "accelerate the development and adoption of advanced building energy technology in new and existing homes" (U.S. Department of Energy, 2012).

Team UOW's core philosophy was to inspire the Australian community to embrace sustainable retrofitting technologies. They wanted to create a demonstration that could be easily applied to current, low performing houses throughout Australia. During the development of the house, compromise was needed - to match the philosophy of the team with the requirements of winning the competition. In addition, to meet the challenge of transporting a house in shipping containers to the competition site further compromises were required. The final, built Illawarra Flame house is represented in Figure 4.

The author was the Design, Construction, and WHS Manager for Team UOW. Similar to the previously reviewed case studies, the team needed to manage the project to a successful result which required the evaluation of hundreds of decisions with reference to the teams core philosophy, and the requirements of the competition - to ensure a desirable competition outcome. This process proved to be layered with challenges (not completely unexpected) that stemmed from two factors. Firstly from the various direct and indirect stakeholder objectives and influences, and secondly, human resources. The greatest challenge with human resources was individual knowledge, skill level and practical application/experience. The undertaking of the Illawarra Flame house was different to a project ever experienced by any of the team members. To bring context to the discussion of the two challenges, an overview of the team and its organisational structure is provided in the following.

Figure 4: The Illawarra Flame House.

The Team - Team UOW

The team was coordinated by the University of Wollongong, under the guidance of Prof. Paul Cooper, Prof. Tim McCarthy and Dr Zhenjun Ma. Team UOW was a real example of multidisciplinary collaboration, led by students and consisted of university students from different fields and backgrounds, who worked alongside with student from TAFE NSW, local government, and an array of industry partners, sponsors, media and advertisement organisations.

Team UOW comprised approximately 65 students (45% engineering, 35% marketing and graphic design, 15% TAFE, and 5% other), who contributed in various capacitates during different (or all) stages of the project, and 10 academic coordinators, and 7 technical staff.

Project Organisation Chart

The organisation chart of Team UOW was developed, revised and implemented at the early stages of the project (early June 2012). The project was managed by a Project Manager, who reported to the Governance Committee and Management Committee. The organisation chart for Team UOW can be found in Figure 5.

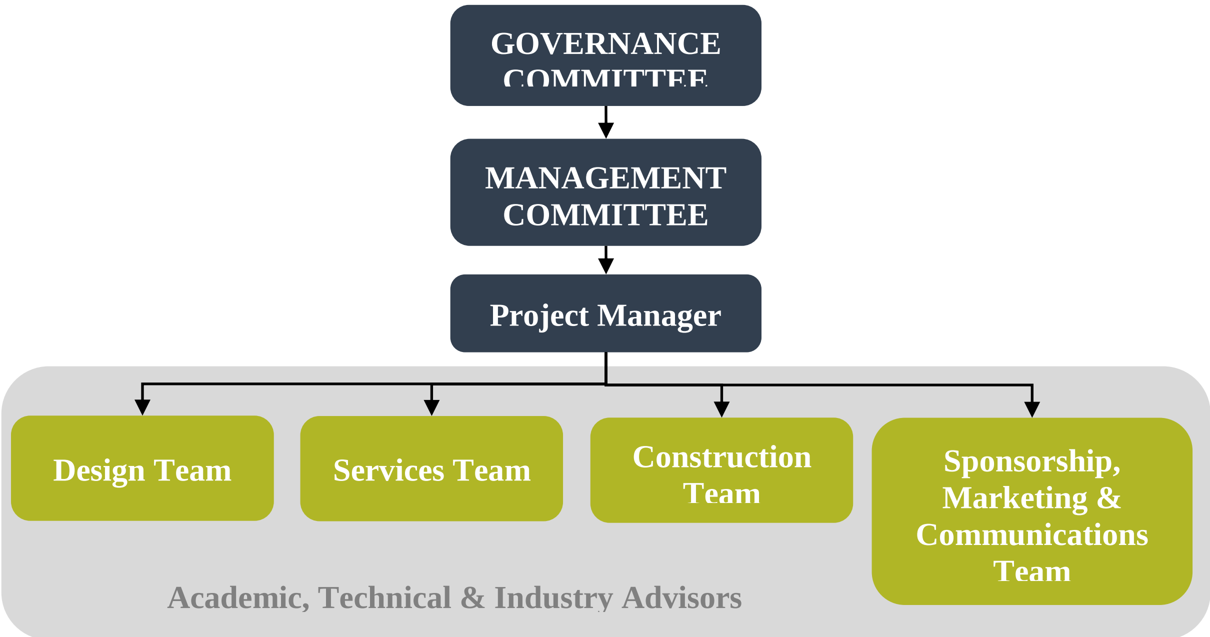

Figure 5: Team UOW Organisation Chart.

In each team, there were designated students, although some students worked under multiple teams. A student was involved in the project for several reasons: volunteering, subject requirement (e.g. assignment based), work experience, and in some specific instances paid work. A volunteering student was able to join any team, and be involved in any context that they wanted.

As stated, this organisation chart was developed and concluded upon early on in the life of the project. This organisation chart was based on the typical structure of a tier 1 construction project. Holistically, this project structure worked well in ensuring definitive actions were achieved through: self-management of each team by the assigned Team Manager (TM), and the adoption of a Management Committee (MC) - strategically placed between the Governance Committee (GC) and Project Manager (PM). The MC, and the surrounding organisation structure, allowed for effective communication between the project sponsors (GC) and the TM. Each TM was responsible for determining their short and long term deliverables - which were presented and reviewed at the MC meetings. The MC and the PM were tasked to ensure these deliverables were in alignment with the overall project objectives.

<u>Key Project Stages</u>

The key project stages were:

1. Project Commissioning

Develop Team UOW’s entrant proposal, lodgement and acceptance into the Solar Decathlon Competition 2013.

2. Concept Design

The development of the concept design was with respect to a 1973 Department of Housing floor plan. The concept design outlined the extent of changes that would be made to the existing floor plan and the high-level concept of the services design that would meet competition requirements.

3. Detailed Design

The detailed design for the Illawarra Flame involved the design of the electrical systems, hydraulic systems, HVAC systems, fire system, services integration, structural design, assembly and disassembly protocol, material selection and architectural detailing. In addition, this stage also required the completion of 'For Construction' documentation.

4. House Construction (initial)

The initial house construction was the fourth stage in the project, and required the construction of the home. The initial construction went for approximately 3.5 months, and was mainly constructed by a team of work experience UOW students.

5. Trial Run (public display and preliminary testing)

The trial run stage was a combination of practicing disassembly and reassembly of the house in a reduced time line (then that given by the competition in China) - risk mitigation, and to display the house to the local public and all of the associated stakeholders to the project.

6. Solar Decathlon Event

The sixth and final stage was the competition event. This stage required the assembly, testing, operating and displaying of the house during the competition period. The evaluating of the houses was over 10 days, with the final ruling given on the last day of the competition.

Challenge One: Stakeholder Management and Achieving Project Objectives

The project started with a design concept stage. This stage (as well as the detailed design stage) was 'designed by committee' which largely comprised UOW Staff Members, TAFE Staff Members, team sponsors and - most importantly - the students. Deriving the concept was the first major milestone for the team, as the concept signified the direction the house would eventually take. This therefore created the first stakeholder management challenge. In retrospect, the greatest challenge was that each stakeholder group had a different view of how to progress the project forward and what most appropriate design concepts, ideas, form, function, materials and details should be. This was made more complicated by the addition of the following design considerations: disassembly, transport, re-assembly in 10 days, Chinese site conditions (i.e. lot size, crane size, WHS, available labour and storage yard protocols) and final building performance. Aligning the concept and progressing forward required the justification, and weighing of each stakeholder's perception. The greatest difference in stakeholder opinion was in the experience between the academic staff and the project manager, and the design, construction and WHS manager and the services manager. The academic staff and the project manager wanted to ensure the house was innovative, collaborative, and related to student research projects. Whereas the design, construction and WHS manager and the services manager focused their efforts on delivering the 10

competition criteria as efficiently as possible - this led to trying to keep the concept and design as simplified as possible. This challenge led to an intensive, 4 month design iteration process. The author felt that this project structure fostered a 'healthy' debate between the two key purposes of the competition, innovation and practical application. Therefore, the organisation chart, which prioritised the stakeholder objectives, not only allowed the team to develop a final building and services design that was highly innovative, but also facilitated efficient dismantling, transport, assembly, and operation.

Challenge Two: Human Resource

Human resource (HR) was a risk to the project, this challenge was experienced by each team during each project stage. The recruiting of the key team members commenced just after the project commissioning stage. These key members were recruited as research masters students and PhD candidates, with their research objectives tied to the project outcome/s. At this time, the organisation chart was derived. The HR challenge was experienced in several ways, specifically: number of available students; time available by students; and skill level of students. During the different stages of the project, the project required different number of students completing different tasks that were overseen by the different TM.

The initial approach was to recruit student volunteers from the various faculties; typically this was not a successful method. In retrospect, it is suggested that this was because each volunteering students primary objectives was their subject grades, and work. In the initial stages, the most committed students were those who had their subject grades associated with their specific deliverables of the team (e.g. structural analysis). On the other hand, due to the rigid nature of the TAFE curriculum, it was difficult for a student to gain credit towards their subjects - which resulted in a lower level of input by TAFE students.

A high level of commitment student recruitment and participation was evident when the student's primary objective (their grades) and the objectives of the project were aligned. This approach was used during the middle of the detailed design stage of the project.

<u>The Success of the Illawarra Flame House</u>

On the 11th August 2013 Team UOW were announced as winners of the Solar Decathlon China 2013, with a record breaking score of 957.6 out of a possible 1000 points, the results of the individual contest were (Team UOW, 2013):

- Juried Contests (qualitative)
  - First place in 'Engineering'
  - First place in 'Architecture'
  - First place in 'Solar Application'
  - Second place in 'Communications'
  - Second place in 'Market Appeal'

- Measured Contests (quantitative)
  - Joint first place in 'Energy Balance'
  - Joint first place in 'Hot Water'
  - Second place in 'Appliances

2.5 Chapter Conclusion

This chapter presents a literature review aimed at defining sustainable development, and its relationship to the building development industry. It outlines best practice in benchmarking sustainable outcomes using key sustainable development objectives and indicators, best practice in applied sustainable rating tools, and the practical application of sustainability in the residential marketplace. The literature review has revealed the significant impact our built environment has on natural resources and energy demands - which makes any efforts in reducing the impact a high priority. The final goal of sustainable development is to make comfortable, affordable, pollutant free, net-zero carbon (over the life-cycle of the development) houses/buildings common practice within the building development industry.

The most established concept for a sustainable development is based on the triple bottom line principle, where a development must balance the social, financial and financial needs, while abiding by a single quote, by Brundtland (1987) “development which meets the needs of the present without compromising the ability for future generations to meet their own needs”. With this concept up-front and centre, the theory of sustainability and sustainable residential developments can begin to be explained and understood, but needs to be practical in real-world application.

For any project, clear objectives and indicators (also known as Key Performance Indicators - KPI) are paramount in ensuring effective benchmarking, monitoring and evaluating of project successes and shortfalls. The traditional development objectives need to evolve to incorporate sustainability consideration. Dair and Williams (2006) and Robichaud and Anantatmula (2010) agree that sustainable development objectives instil flexibility to choose and apply specific sustainability measures (KPI), tailored specifically to each development. It is also important to separate key sustainable objectives against the three themes of sustainability. This is critical in the effective evaluation of key performances of the development against each theme, which provides a pragmatic evaluation of project decisions with respect to the project's overall sustainability credentials. After a review of the sustainable objectives and indicators proposed by other researches, a tailored set of objectives were derived with specific reference to Dair and Williams (2006) proposed sustainable development objectives. The key amendments to their proposed objectives were in placing the objectives in the perspective of the commissioning client, as given in Table 4**:** Sustainable Residential Development Objectives. The specific changes were in relation to the 'social objectives', they were tailored to the delivery of the social requirements of the client. Integrating the development within the locality and ensuring the culture and heritage of the development is considered a social objective for the local and state governments.

Table 4: Sustainable Residential Development Objectives.

Themes of Sustainability	**Sustainability Objectives**
Economic Objectives	To enable business to be efficient and competitive
	To support local business diversity
	To provide employment opportunities
	Manage client budget with project expenditures
Social Objectives	To adhere to ethical trading standards and fairness-at-work policies
	To provide adequate local services and facilities to serve the development
	To provide housing to meet the needs of the client
Environmental Objectives	To minimise the use of resources (materials and operation)
	To minimise pollution
	Protect biodiversity and the natural environment

CHAPTER 3. A REVIEW OF PROJECT MANAGEMENT AND DECISION-MAKING IN BUILDING DEVELOPMENTS

The aim of this chapter is to critically review literature in two associated areas, project management and decision-making - each reviewed in the context of sustainable building developments. Starting with project management, the first research objective was to bring reference to the field by identifying the origins of project management and presenting the widely adopted PMI (2008) project management philosophy, and then comparing current 'green' project management frameworks. The chapter then focuses on managing project risks though identification and mitigation. The chapter identifies the importance of effective stakeholder management, and key considerations and approaches specific to construction projects. The chapter also focuses on effective and applicable decision-making methods, by identifying limitations and advantages to specific qualitative and quantitative methods.

At the conclusion of this literature review, methods for adopting project management and decision-making are summarised against their applicability to effectively deliver sustainable residential developments.

The chapter concludes by addressing the chapter objectives outlined in Table 5.

Table 5: Chapter 3 Research Objectives, Project Management & Decision-Making.

<table>
<tr><th>OBJECTIVES</th><th>TASK</th></tr>
<tr><td rowspan="5">Investigate project management current best practices for delivering building developments</td><td>Review the origins and concept of project management.</td></tr>
<tr><td>Examine the philosophy of the PMBOK Guide, investigate and present current project management methodologies for delivering 'green' buildings.</td></tr>
<tr><td>Suggest approaches for successfully identifying project risks, failures and successes.</td></tr>
<tr><td>Identify approaches to stakeholder management.</td></tr>
<tr><td>Suggest approaches for successfully integrating sound project management practices for the delivery of sustainable developments.</td></tr>
<tr><td rowspan="3">Suggest ways to improve conventional decision-making methodologies and tools.</td><td>Review of quantitative and qualitative decision-making methods.</td></tr>
<tr><td>Examine advantages and limitations for each decision-making methods.</td></tr>
<tr><td>Suggest approaches for successfully integrating sound decision-making methods into the delivery of sustainable developments.</td></tr>
</table>

3.1 Putting Project Management into Practice

The project management profession first established itself in the civil construction industry in the early 20th century, where it has grown into almost all facets of business. Since then, project management has proven itself as an integral requirement for achieving project requirements and overall project success (Hwang and Ng, 2013). The success of a project, and project management processes itself can partially be attributed because it "...operates in an environment broader than that of the project itself" (PMI, 2008). Given that project management represents such a significant element with defining and delivery of building projects, its consideration and integration are vital to the success of sustainable developments (Eid, 2003, Robichaud and Anantatmula, 2010). Eid (2003), Robichaud and Anantatmula (2010) and Doloi (2007) all agree on the importance of the project management process for implementing sustainability into building and infrastructure developments.

3.1.1 Project Management Body of Knowledge (PMBOK)

The Project Management Body of Knowledge (PMBOK) (PMI, 2008) is an internationally leading guide for best practice in project management. The purpose of PMBOK is to identify the core project management framework and knowledge groups generally recognised as 'good practice'. PMBOK (2008) describes project management as "...a set of interrelated actions and activities performed to achieve a pre-specified product, result or service." The interrelated actions and activities over a projects life are described to act within a matrix of ‘Process Groups’ and ‘Knowledge Areas’. PMBOK (2008) outlines five different project management process groups that interact at varying intensities over the life of a project. The process groups described by PMBOK are: Initiating Process Group, Planning Process Group, Executing Process Group, Monitoring and Controlling Process Group, and Closing Process Group. Figure 6**:** Process Group Interaction During Project Life (PMI, 2008) graphically illustrates the varying intensities of each process groups during a project life.

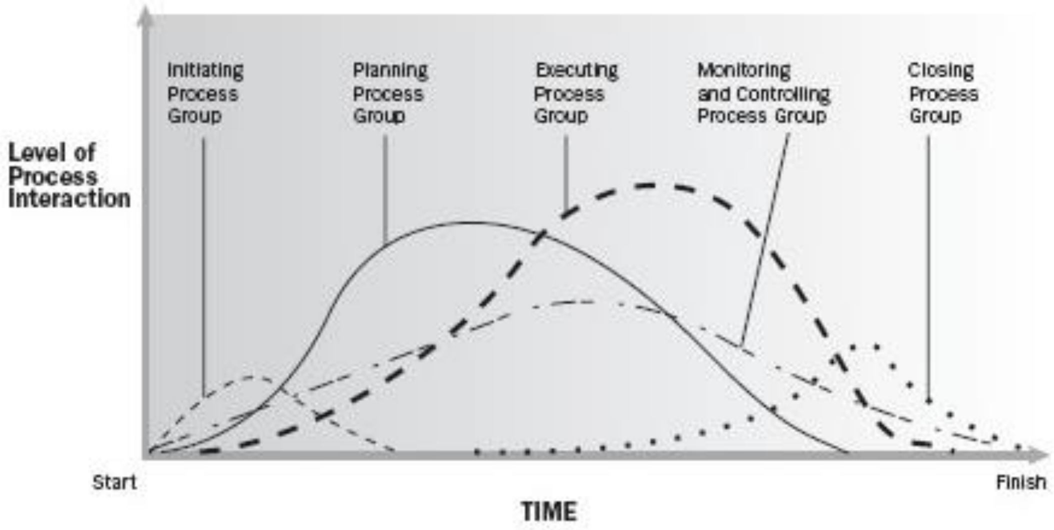

Figure 6: Process Group Interaction During Project Life (PMI, 2008).

The iterative nature of project management means the process of any group has a corresponding knowledge area and required action. The interrelationship between the five process groups, and the nine knowledge areas are outlined in Table 6. This table also outlines the expected 'actions' that need to be undertaken at each junction for any given project. These actions are tailored for each type of project (i.e. construction or events) and each specific project.

Over the life of a project, each process group is utilised at different intensities to support different needs required from varying project types, and during various stages of a projects life. Each of the knowledge areas contribute to the body of knowledge required for project management best practices, and each have specific tasks that need auctioning at specified timings during a project life cycle. The specified actions that need to be completed, at each stage of a projects life are outlined in Table 6**:** Process Groups and Knowledge Areas Matrix (PMI, 2008).

Table 6: Process Groups and Knowledge Areas Matrix (PMI, 2008).

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	**Planning Process Group**	**Executing Process Group**	**Monitoring & Controlling Process Group**	**Closing Process Group**
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Execution	4.4 Monitor and Control Project Work 4.5 Perform Integrated Change Control	4.6 Close Project or Phase
5. Project Scope Management		5.1 Collect Requirements 5.2 Define Scope 5.3 Create WBS		5.4 Verify Scope 5.5 Control Scope	
6. Project Time Management		6.1 Define Activities 6.2 Sequence Activities 6.3 Estimate Activity Resources 6.4 Estimate Activity Durations 6.5 Develop Schedule		6.6 Control Schedule	
7. Project Cost Management		7.1 Estimate Costs 7.2 Determine Budget		7.3 Control Costs	
8. Project Quality Management		8.1 Plan Quality	8.2 Perform Quality Assurance	8.3 Perform Quality Control	
9. Project Human Resource Management		9.1 Develop Human Resource Plan	9.2 Acquire Project Team 9.3 Develop Project Team 9.4 Manage Project Team		
10. Project Communications Management	10.1 Identify Stakeholders	10.2 Plan Communications	10.3 Distribute Information 10.4 Manage Stakeholder Expectations	10.5 Report Performance	
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses		11.6 Monitor and Control Risks	
12. Project Procurement Management		12.1 Plan Procurements	12.2 Conduct Procurements	12.3 Administer Procurements	12.4 Close Procurements

Although projects vary in context, size and complexity, PMI (2008) explains that every project can be mapped to the generic life cycle structure. The generic life-cycle structure of any project considers four main project deliverables. From project phase to project phase – achieving each deliverable, PMI (2008) graphically highlights the four key variables for any project; project expenditure rate, staffing, risk and stakeholder influence over time. At the initial stages of a project, project staffing and expenditure rate a relatively low with respect to delivering the project outcomes, although at this stage, stakeholder influences, risk and uncertainty are high. When a project progresses past project management planning, the true cost of enacting the project deliverables are felt and the cost of changes are amplified, also the stakeholder influence and risk is in part reduced. Figure 7 illustrates this relationship between project life cycle phases and the staffing and expenditure rate. While Figure 8 illustrates the relationship between stakeholder influence, project risk, project uncertainty and project variation costs over the life of a project.

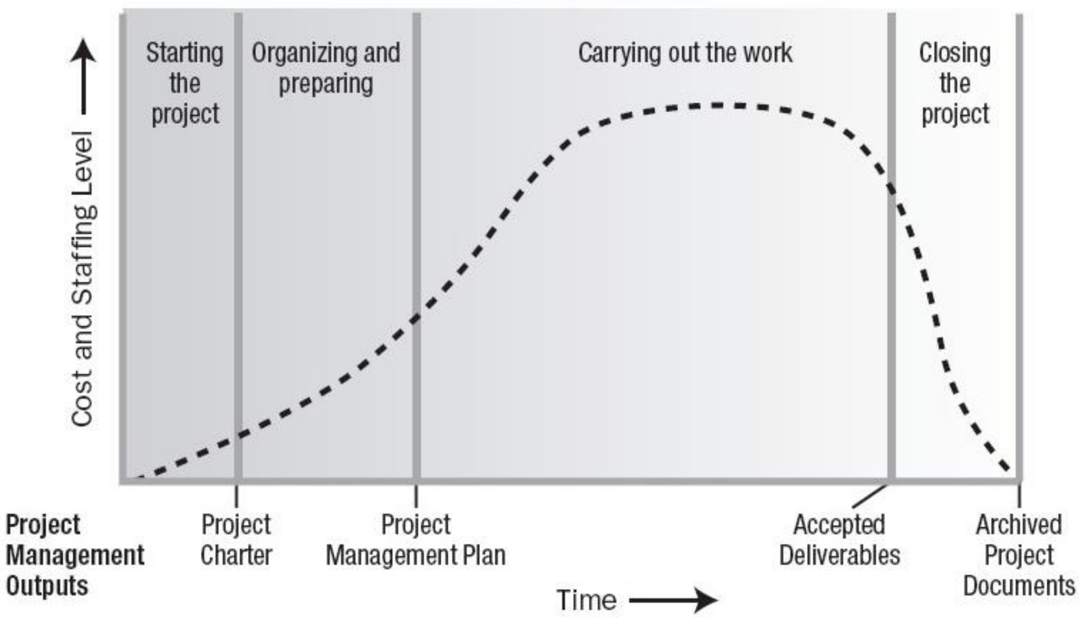

Figure 7: Typical cost and staffing levels of across the project life cycle (PMI, 2008).

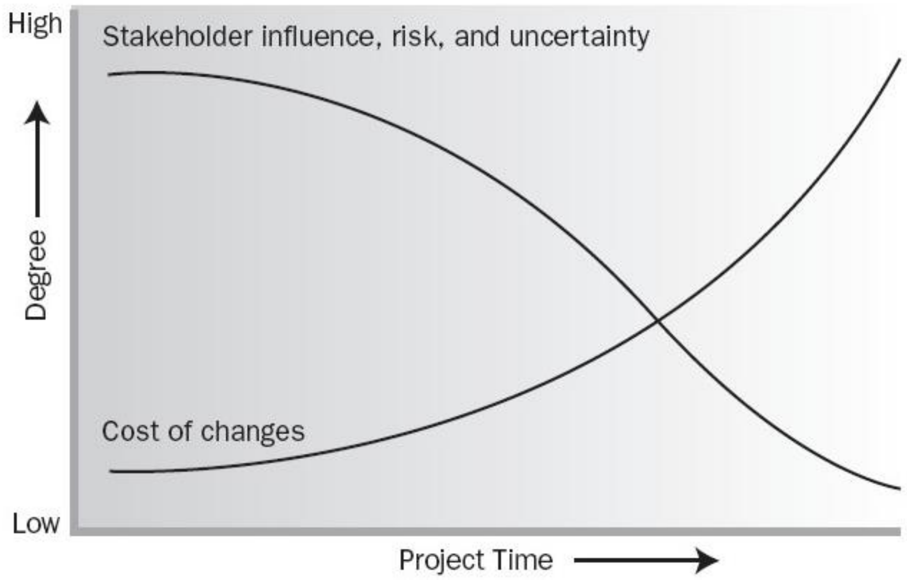

Figure 8: Change in stakeholder influence, risk, uncertainty and variations over project time (PMI, 2008).

Understanding the importance of each process group (in addition to the associated knowledge areas and required actions), and their connected succession during a project is critical to overall management of key project requirements - the bigger picture.

3.1.1.1 Project Management Body of Knowledge (PMBOK) Process Groups

As noted previously, each of the process groups are critical to an overall, effective implementation of a management plan and therefore the delivery of a successful project. Over the life of a project, the management will draw upon five process groups, beginning with the initiating process group.

<u>Initiating Process Group</u>

The initiating process group (IPG) signifies the starting point of any project, which is instigated by the project sponsor/s, and "...consists of those processes preformed to define a new project or a new phase of an existing project by obtaining authorisation to start the project phase." (PMI, 2008). The important component of the IPG phase is the delivered product, named the 'Project Charter' by PMBOK, or in building developments, the 'Project Brief' or 'Client Brief'. The project charter is a document that formally initiates the project and outlines the requirements of the project that satisfies the stakeholders' needs and

expectations from a project. The project charter also recognises the internal and external stakeholders, project boundaries, project feasibility and associated project risks (PMI, 2008). Figure 9 outlines the high-level process to create a project charter.

In addition, the IPG is the starting point for the development of the 'Project Management Plan', in which all future management of the project develops from. Eid (2003) concluded in his work that this early stage, the project charter, had the most effect on a projects overall direction and the projects efficiency of delivery, and therefore the most effectual leverage point for creating sustainable developments. In addition, Vanegas (2003) also outlined that this phase within a project "...has [the] greatest potential to influence overall project sustainability at lowest cost.". Vanegas (2003) considered that each phase in a sustainable development is important over the outlined key areas: Sustainable Planning Phase (Project Integration Management), Sustainable Design Phase, Sustainable Construction Phase and Sustainable Operations phase. The research continued to outline that the initiation phase (a subset of the Sustainable Planning Phase) of a project holds the greatest impact on a projects overall sustainability.

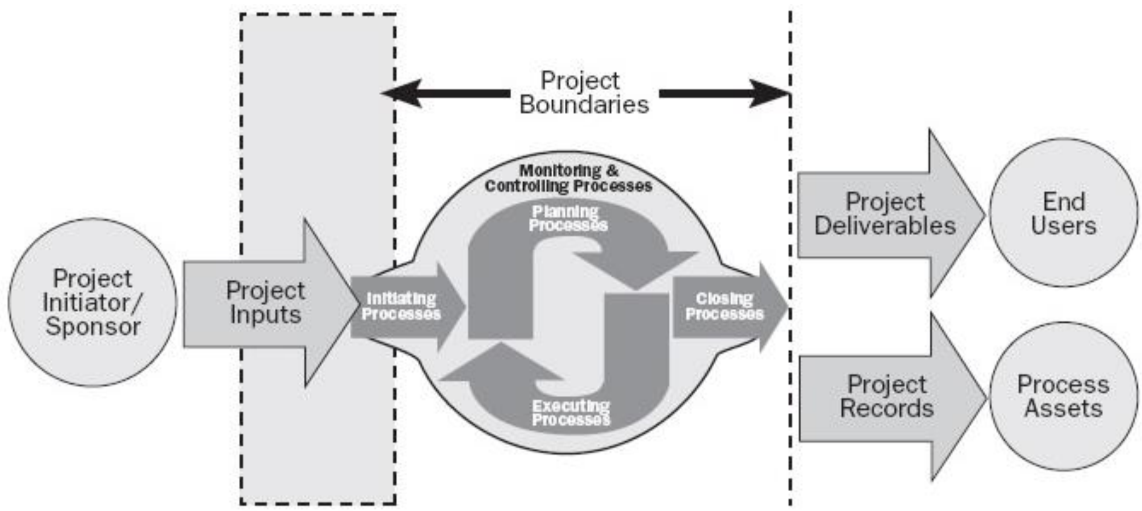

Figure 9: Initiating Process Group Procedure (PMI, 2008).

Planning Process Group

The planning process group consists of the process and actions performed "to establish the total scope of the effort, define and refine the objectives, and develop the course of action required to attain the objectives." (PMI, 2008). The planning process revolves around the project integration management knowledge area, and associated actions to develop the 'Project Management Plan' - a process which documents "...the actions necessary to define, prepare, integrate, and coordinate all subsidiary plans." (PMI, 2008). In addition, the incorporation of documented processes and actions are critical to create feedback loops for monitoring and analysis operations. The planning process group is outlined in Figure 10.

The project management plan, for any project, becomes the primary source of information on "...how the project will be planned, executed, monitored and controlled, and closed." (PMI, 2008). The development of the project management plan begins with the project charter, required outputs from the planning processes, project environmental factors, and organisations processes assets/environmental factors (internal and external organisations). With reference to the project commission documents (input), the project management plan will be developed and outline the following information:

- Defined project scope
- Project Work-Breakdown-Structure
- Defined project activities
- Sequence of activities
- Duration of activities
- Resources to complete each activity
- Project schedule (with reference to the previously defined items)
- Project costs for each activity
- Define overall project budget
- Define project quality expectations
- Human resources plan
- Project communications plan
- Project risk management plan (inc. risk identification, qualitative and quantitative risk analysis, and risk mitigation options)
- Project procurement plan

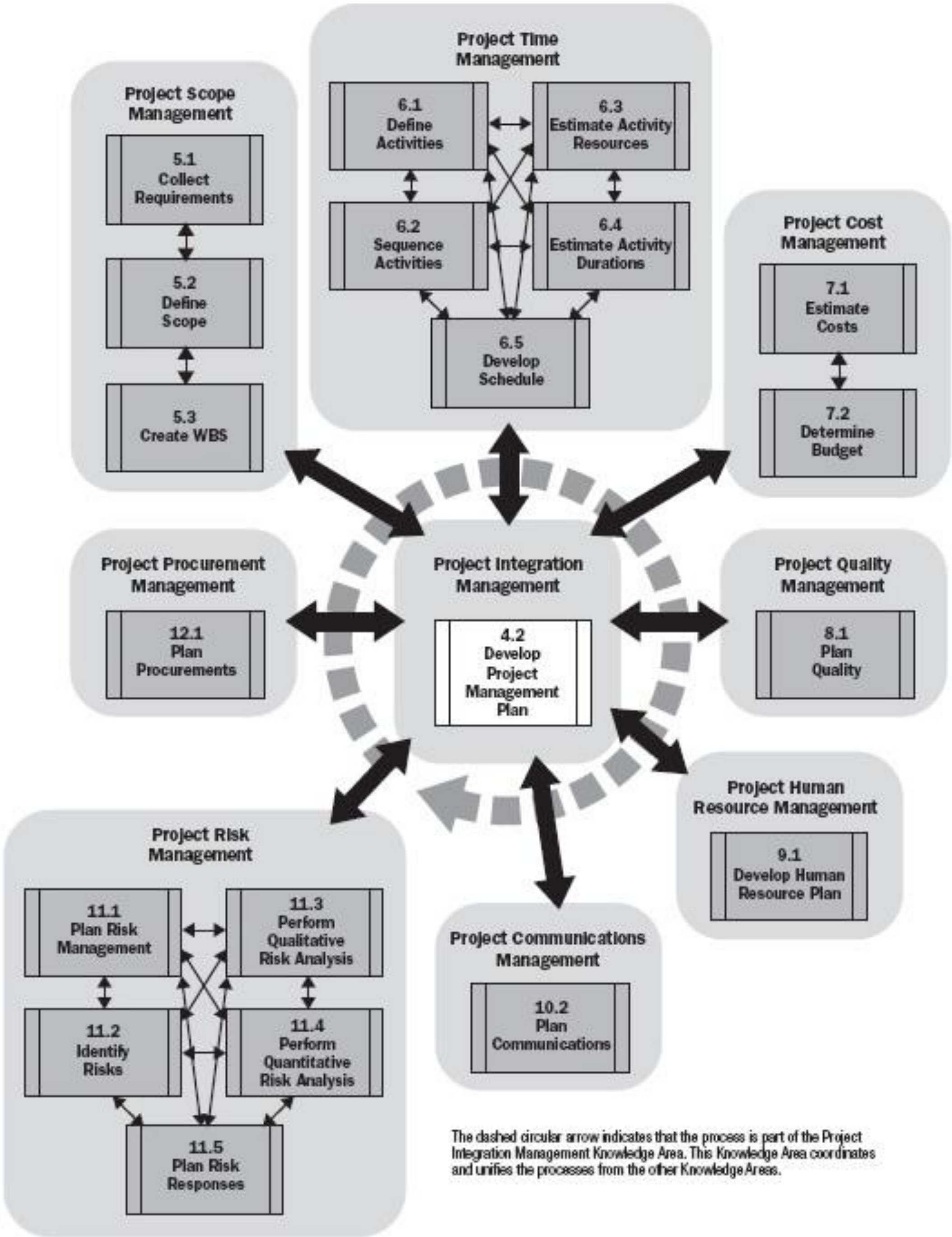

Figure 10: PMBOK Planning Process Group (PMI, 2008).

Executing Process Group

"The Executing Process Group [(EPG)] consists of those processes performed to complete the work defined in the project management plan to satisfy the project specifications." (PMI, 2008). To deliver any project, it requires the coordination of people and resources to fulfil the overall project objectives. The project management plan outlines an integrated arrangement of activities to most effectively deliver project performances and specifications. The EPG comprises of four associated knowledge areas - with their specified actions, surrounding the project integration management knowledge area. Within this process group, the project manager/team shall action the following:

- Execute the project management plans
- Acquire required team members
- Develop team members (improve individual and team effectiveness)
- Manage project team
- Clearly distribute project information
- Manage stakeholder expectations
- Project procurement (in accordance with the management plan)
- Project quality assurance (as specified by the management plan)

The executing process group is outlined in Figure 11.

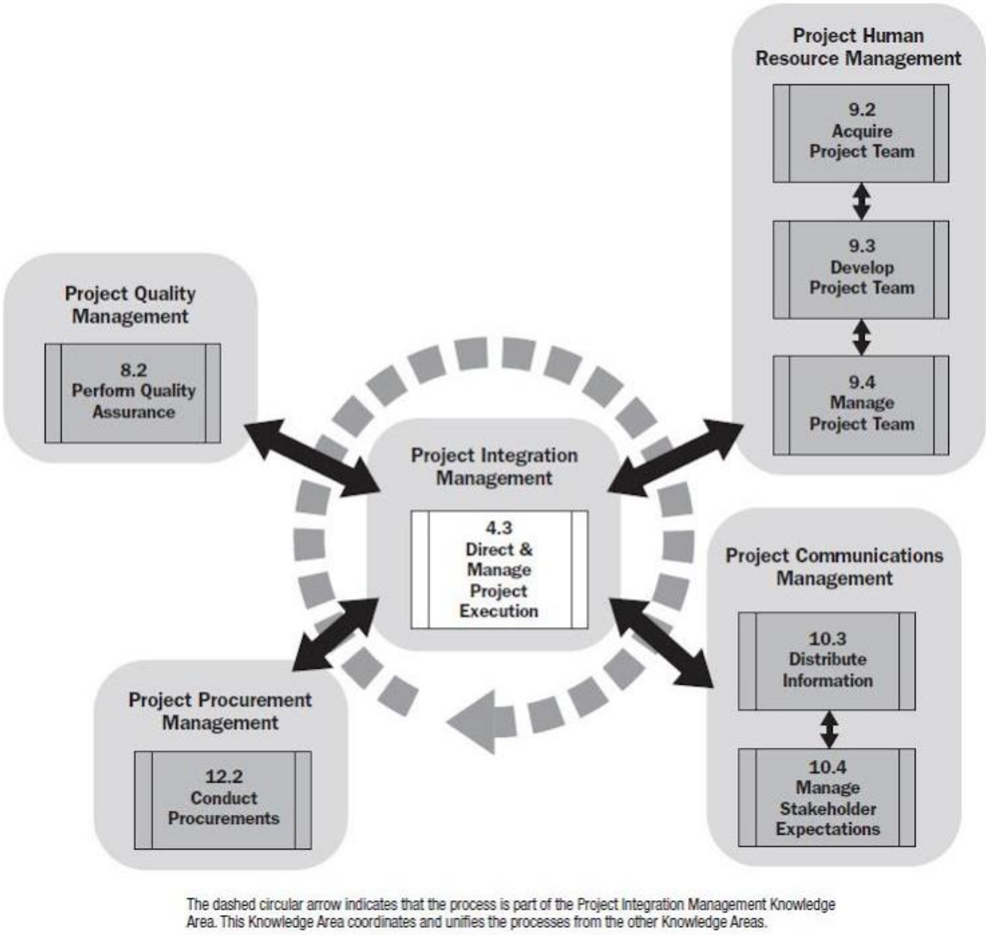

Figure 11: PMBOK Executing Process Group (PMI, 2008).

<u>Monitoring and Controlling Process Group</u>

The monitoring and controlling progress group of PMBOK consists of the processes required to track, review, and regulate not just project progress but also project performances. Regular monitoring of project progress and performance allows for the identification of variances in between implementation and project planning. This allows the project team to identify areas of the project that change is required, and apply appropriate responses to implement, where required, corrective change (PMI, 2008).

The monitoring and controlling process group outlined by PMBOK in Figure 12 illustrates the connected nature this process group has on the other project processes. This is a core management process, to ensure that the project scope, project specifications, project risk project communication, and project constraints are managed effectively. In addition, this allowed integrated approach to guiding ongoing decision-making to appropriate resolutions.

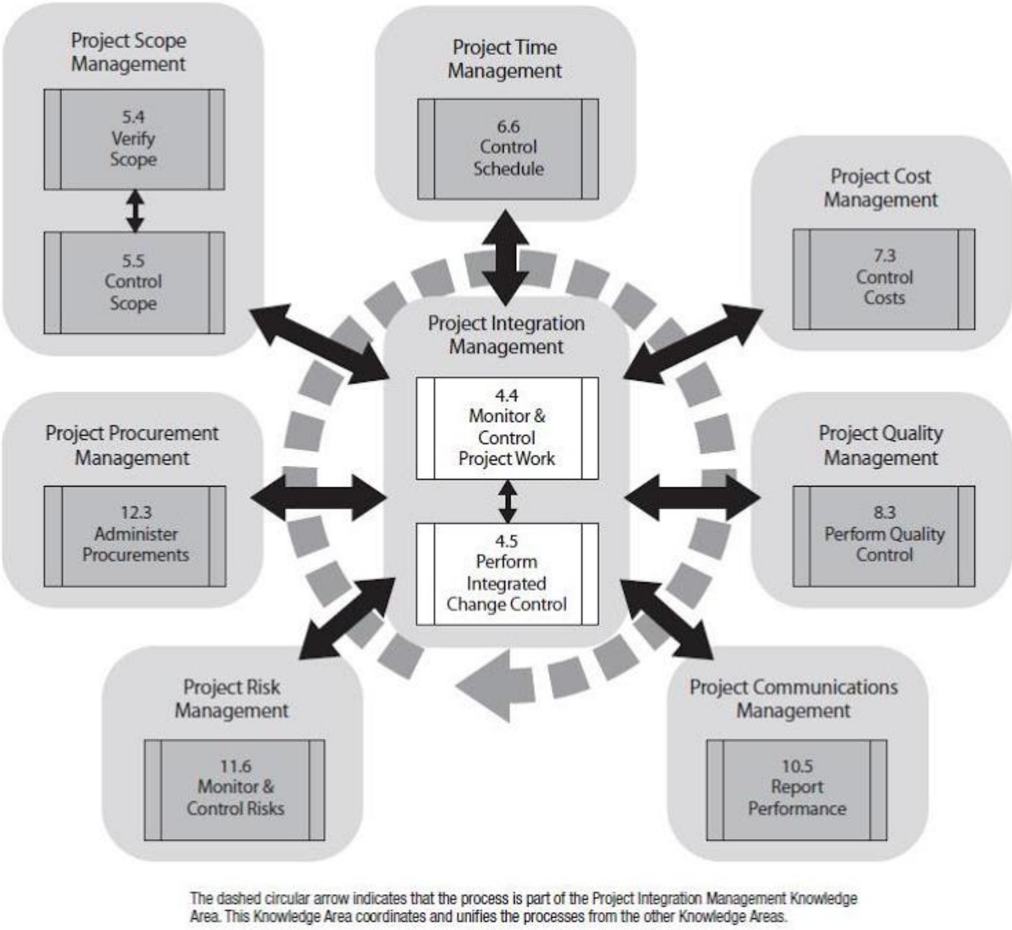

Figure 12: PMBOK Monitoring & Controlling Process Group (PMI, 2008).

Closing Process Group

As the name suggests, the closing process group consists of all the processes required to finalise all activities across all of the project process groups. Finalising this process group establishes that the project has come to a final close. During this process, there are several important actions that may occur (PMI, 2008):

- Obtaining acceptance by the customer or sponsor
- Conduct post-project or phase-end review
- Record impacts of tailoring to any process
- Document lessons learned
- Apply appropriate updates to organisational process assets
- Achieve all relevant project documents
- Close out procurements

The closing process group is outlined in Figure 13.

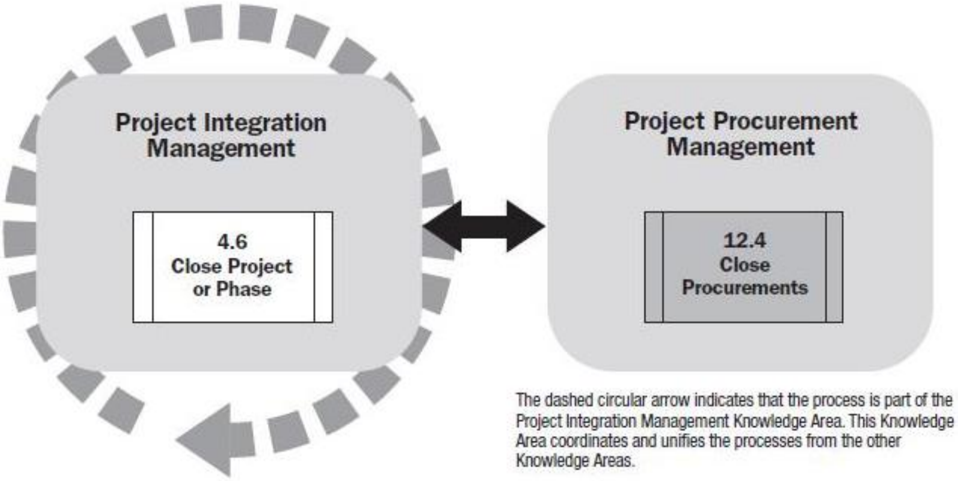

Figure 13: PMBOK Closing Process Group (PMI, 2008).

3.1.2 Greening Project Management Practices, Comparing Current Green Project Management Trends with PMBOK

As outlined in the introduction of the work, project management seems to be the best approach to ensuring the most successful, and balanced sustainable outcome in buildings. There has been several attempts to adopt a 'green' project management practice in the effort to create ever more sustainable building outcomes. In this research, three have been considered relevant, and investigated in more detail.

3.1.2.1 Eid (2003) Approach to Greening Buildings Through Project Management Practices

Eid (2003) explains the potential benefits of integrating sustainability into project management processes, practices and tools in the construction industry. This is because of the large influence the project management processes have on delivering successful project outcomes. By adopting sustainability, with respect to sustainable objectives derived from triple bottom indicators, throughout the project management area of knowledge (presented by PMI (2008), sustainable outcomes can be achieved. However, Eid (2003) is yet to develop a

methodology, framework or applied processes to test his hypothesis. The theory is illustrated in Figure 14.

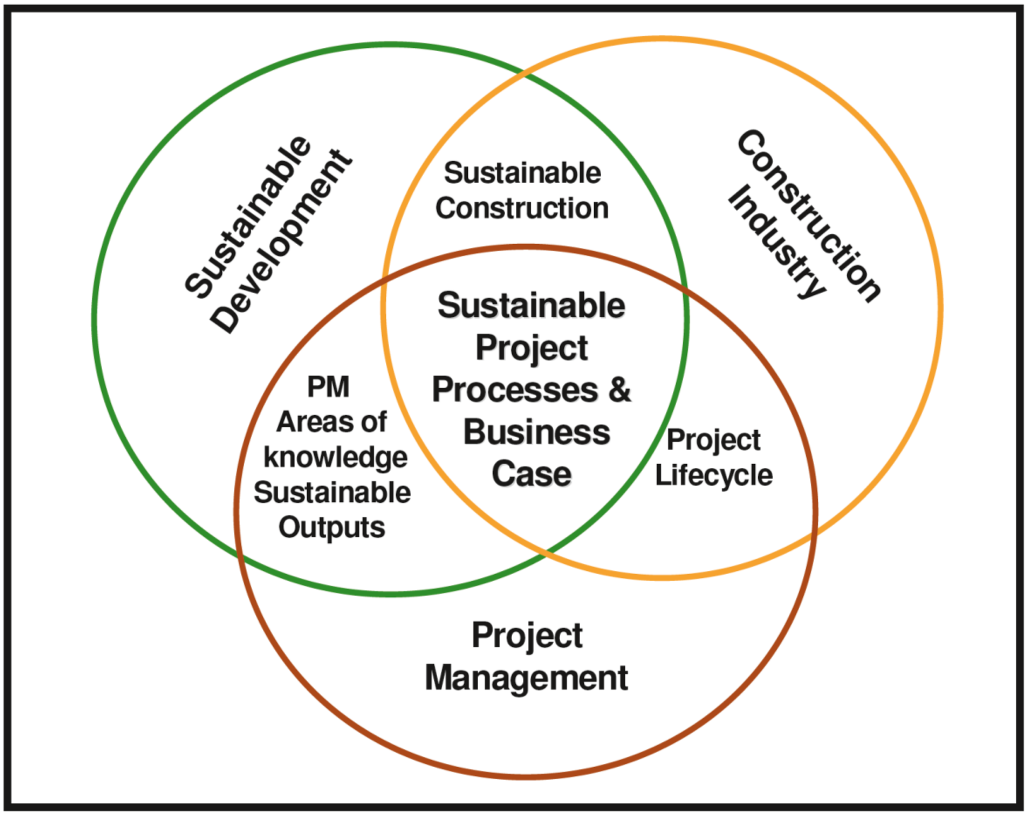

Figure 14: Integrating the Three Element (Eid, 2003).

3.1.2.2 Robichaud and Anantatmula (2010) Approach to Greening Buildings Through Project Management Practices

Robichaud and Anantatmula (2010) illustrates that greening project management practices can have the single most significant impact on a projects sustainability outcomes. This research also presents an adjusted project management methodology more suited to delivering the larger, more integrated and complex sustainable projects. The framework proposed within this research is outlined in Figure 15. The framework has aligned itself very closely with PMBOK project stages, the only difference is the 'construction' phase terminology. In addition, the approach also emphasises the importance of two things, firstly outlining the sustainable objectives during the feasibility stage, and secondly project integrating of the project team in terms of specialist (e.g. architects, engineers, and building contractors). The integration of the key design and construction stakeholders is critical in

ensuring the evolution and finalising on the most integrated solution to deliver the greatest project results. In addition, this integrated team approach will also increase project communication and comprehensiveness of documentation to ensure a reduction on 're-work' on the typically large and complex sustainable projects (Robichaud and Anantatmula, 2010).

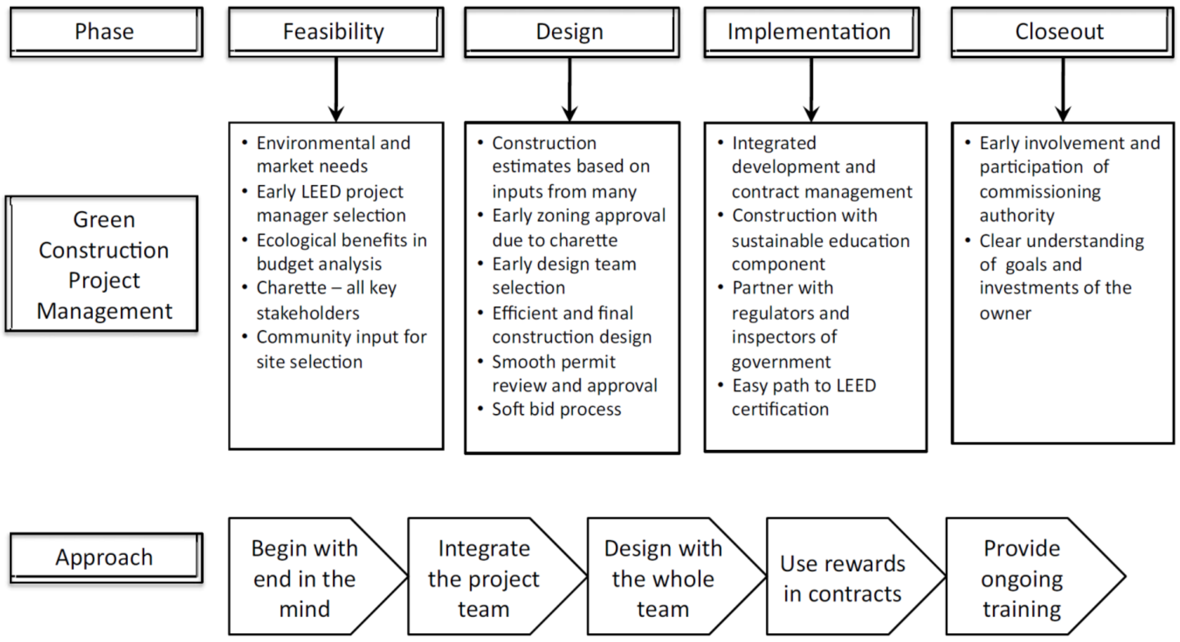

Figure 15: 'Green Project Management' Framework (Robichaud and Anantatmula, 2010).

3.1.2.3 Doloi (2007) Approach to Greening Buildings Through Project Management Practices

This research outlined the inadequacy and unresponsiveness of information to deliver stakeholders, financial planners and decision makers clearer and more holistic information that would otherwise support more sustainable development projects. Entrenching sustainability into the project management processes and areas of knowledge will provide the opportunity for the needed change. Eid (2003) stated that the development of tailored project management techniques and tools would effectively support needed change required to deliver sustainable objectives. However, no evidence of their development is currently available. The aim of this research is to provide the tools needed, through the project management process, to guide decision makers through an integrated balance of environment, economic and social project influences.

Doloi (2007) mapped the holistic project management process through each decision hold point – refer to Figure 16.

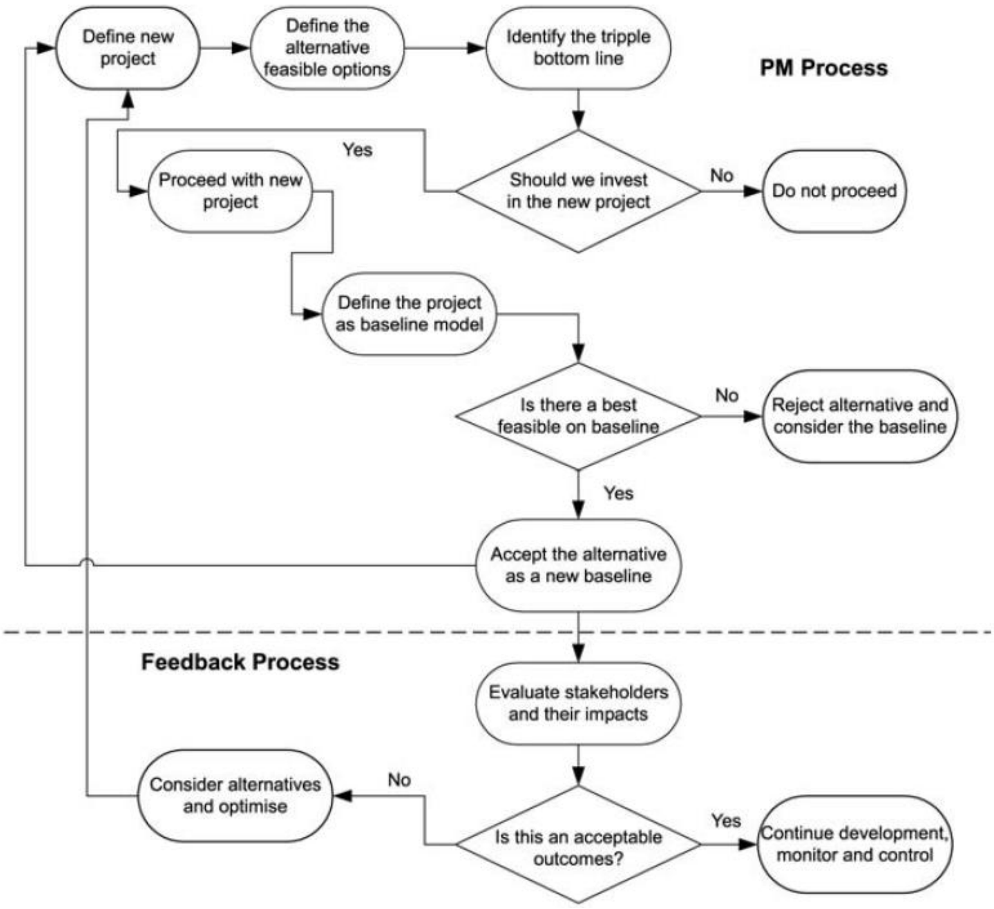

Figure 16: Project Management Decision-making Approach (Doloi, 2007).

3.1.3 Project Risk Management

Risk management has been identified as an important aspect of any organisational structure and operation, with many large firms establishing specific risk management departments with sub-factions to manage potential exposure to risks (Akintoye and MacLeod, 1997). In most cases, managers need to deal with several types of organisational and project associated risks. Zwikael and Ahn (2011) categorise the notable risks as technological, financial, insurance-related, environmental safety and regulatory. Project risks and project risk management add an additional, high layer of risk (associated to the organisation/s). This is innately derived from "...their compressed time schedules, inadequate or uncertain budgets, designs that are near the feasible limit of achievable performance, and frequently changing requirements" (Zwikael and Ahn, 2011). Therefore, construction projects are held as a high-risk

project/industry, involving the potential for high financial losses through the uncertainty embedded in the innate complex interactions of stakeholders, safety, design, regulatory, processes and infinitely associated variables (Akintoye and MacLeod, 1997).

Flyvbjerg (2013) identified that the most significant "...source of risk in project management is the inaccuracy in forecasts of project costs, demand and other impacts". Accurate forecasts of costs remain inaccurate, even with suggested claims of improved forecasting models, data and methods (Flyvbjerg, 2013). For infrastructure projects, Flyvbjerg (2013) outlines that, on average, all road and rail projects compiled in the study were wrong by more than ±20%. Redwood (2009) documented similar results in the regional area of the Illawarra in 2009, where thirteen civil construction project were surveyed which resulted in an average increase in cost of 49% (between estimated construction budgets to final construction costing).

Typically, good practice for risk management is to develop a risk portfolio. This can be completed in a four-stage process. This process will ensure a comprehensive review of the associated project risks and an accurate development of the contingency reserve for the development. The four steps include:

1. Communication and Consultation
2. Risk Assessment
3. Contingency Development
4. Review and Approve

By following the steps, the project team can capture and mitigate any undue risk associated to the project, while also ensuring the project has an adequate contingency reserve in the event a risk occurs. Figure 17 shows the diagrammatical connection of the four steps.

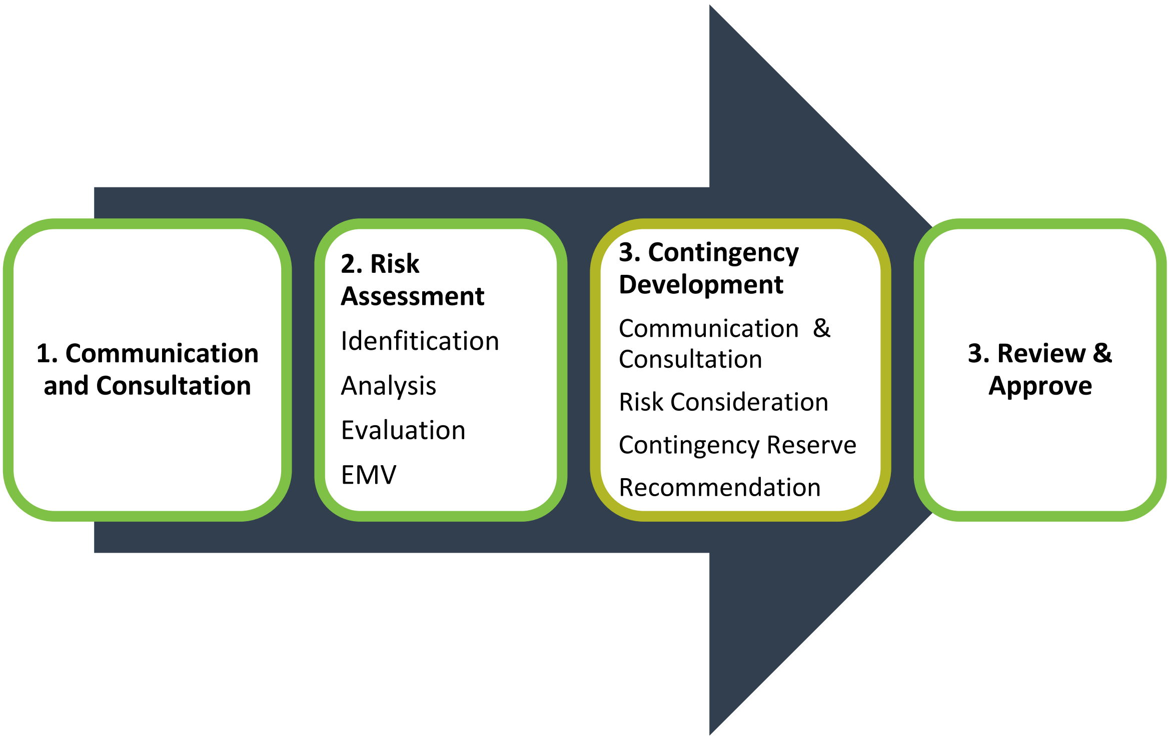

Figure 17: Contingency Reserve Development Process (Redwood et al., 2011).

Communication and Consultation

Communication and consultation with stakeholders in the identification of risks and the development and conclusion of the contingency reserve is considered a critical factor to ensure risks are effectively managed and the contingency reserve is adequate. Therefore, the project team should endeavour to communicate and consult with external and internal stakeholders not just in the onset but also during the contingency reserve development process.

Risk Assessment

The identification of risks should be completed via a brainstorming consultation with all (internal/external) stakeholders. This approach will instil ownership within the stakeholder groups and ensure comprehensive multidisciplinary risk identification.

The identified multidisciplinary risks should be broken down into risk categories, which ensured a consistent level of detail, coverage, linkage and understanding of the identified project risks. An example risk categories and risk breakdown structure is outlined in Figure 18.

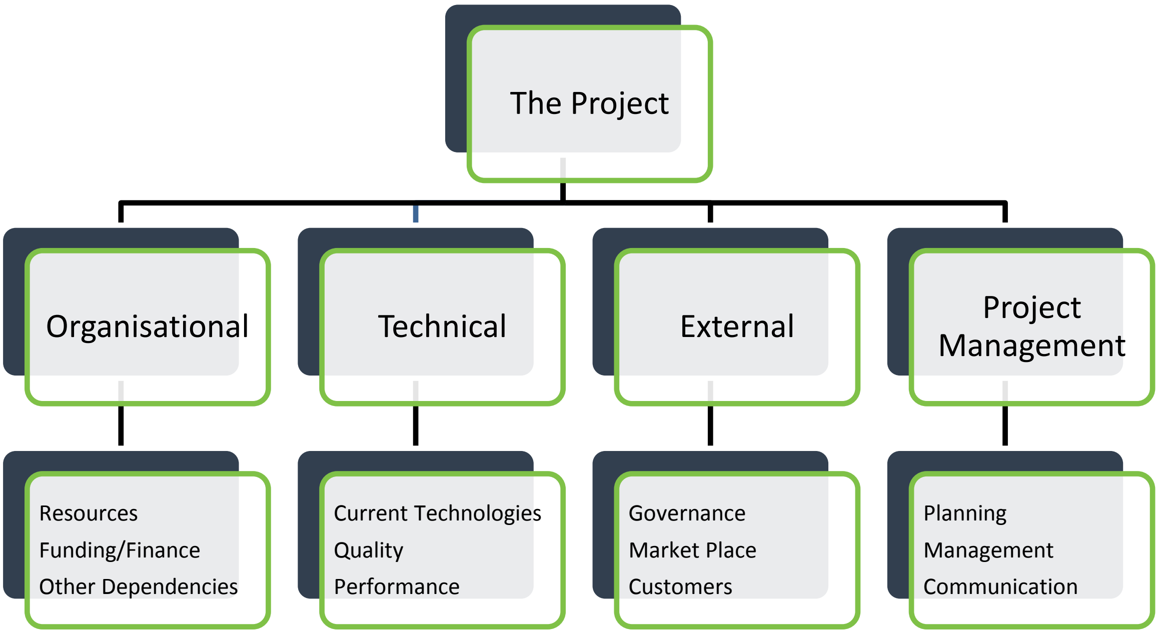

Figure 18: Risk Breakdown Structure (Redwood et al., 2011).

Contingency Reserve

The contingency reserve illustrates a monetary sum used to manage events caused by the identified risks occurring. In this event associated contingency reserve would be used to rectify these issues and/or reduce their impact or risk chain on project outcomes.

Recommendation

The risk profile recommendation will compile all associated project risks, the effect of the associated risk, and the level of contingency required to mitigate the impact of such a risk, or chain of risks occurring.

3.1.4 What Constitutes as a Project Success and Project Failure?

The concept of what constitutes a project failure is nebulous, and few people resonate with this concept (Pinto and Mantel Jr, 1990). During its infancy, failures and limitation in the project management theory were attributed to project scheduling problems, and it took researchers and practitioners several decades to focus on how project successes and failures are defined, and therefore identified (Belassi and Tukel, 1996). The difficulty in determining what constitutes a project success and/or failure stems from the complex network of stakeholders. Each stakeholder involved in the project, at every level, values the project

differently, and therefore derives their own perspective of what constitutes as a project success of failure (Belassi and Tukel, 1996).

For any project manager, and project team it is critical to capture and understand the nature, context and causes of project failures and successes. Any measures to improve a project manager's effectiveness is critical for ensuring future success, as it is estimated that they have an influence on over 34-47% of project outcomes (Hwang and Ng, 2013) - therefore a project managers experience is critical to overall success. Capturing and reflecting on past events will improve the project manager/s and project team/s ability to plan and implement future projects. In addition, this practice has also been seen to identify patterns in project implementation led to project failures (Pinto and Mantel Jr, 1990).

Since the 1940's, the contractual structure/delivery method to align stakeholders (stakeholder incentive and interconnection with the project) to execute building development projects has evolved. Any evolutionary shift is a direct result of an environmental catalyst, over the decades, the catalyst in this case has been an increase in project complexity, which has led to project failures (Kent and Becerik-Gerber, 2010). A recently developed delivery method (i.e. contractual structure to align stakeholders incentives), known as 'project alliancing' is successfully being used in Australia, and more recently adopted in the United States (Kent and Becerik-Gerber, 2010). This new delivery method is founded on the premise of placing a high level of importance of aligning key stakeholder incentives and goals with the overall project objectives. In addition, it has been noticed to innately instils collaborative work, unanimous decisions of key project issues, and brings onus to share and mitigate anticipated project risks (Lloyd-Walker and Walker, 2011).

However a project defines their factors to identify project performances, successes and failures, it has been identified by Pinto and Mantel Jr (1990) that there are three distinct categories (outcomes) that performances, failures and successes are classified against. These categories are (Pinto and Mantel Jr, 1990):

1. Implementation process: This is an internally oriented review of the effectiveness of how the project was delivered.
2. Perceived value of the project: This aspect refers to the externally perceived value of the project; it includes the quality of the delivery, the ability for the project to achieve project objectives and the value for the user/client.
3. Client satisfaction: This is a reflection on the delivery/project team on how well they met the client's needs.

Gaining a greater understanding of what constitutes as a project success and failure will help project managers better plan, benchmark, monitor and validate the effectiveness of the project delivery. In addition, it will allow for a closed-loop in the internal and external evaluation for each completed project, and provide valued feedback and lessons learnt to the ever-evolving skill-sets of the project team.

3.1.5 Managing Project Stakeholder: Their Perceptions, Influences, and Emotions

The development of a building includes all of the influences, decisions and processes that come as part of the condition to deliver the finished building. As outlined previously, stakeholder influence varies over the life a project, with their greatest influence being felt at project initiation and planning phases. The project team must determine the predicted level of influence of each stakeholder, to understand the potential effect when delivering the project objectives (Yang et al., 2009). A project will have internal or external stakeholders, that the project management team needs to identify and manage their expectations and influence (PMI, 2008). PMI (2008) presents the various levels of stakeholders, and their connection to the project in Figure 19.

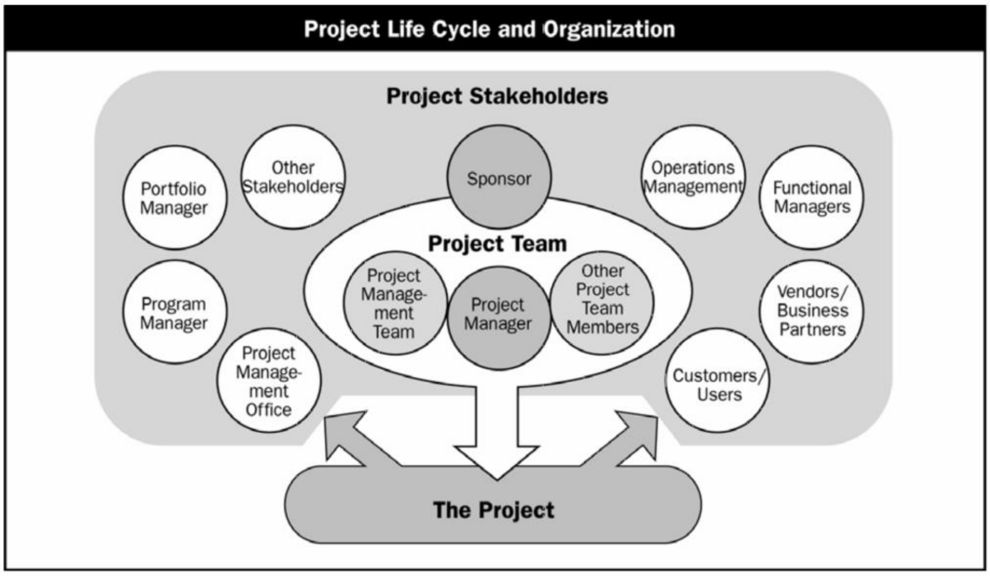

Figure 19: The Relationship Between Stakeholders and the Project (PMI, 2008).

For this research, it is critical to identify the key stakeholder groups and types that influence building development outcomes. Stakeholder management and their influences on project outcomes is a well-documented and researched area, however little research has been conducted with stakeholder involvement and influence with aspects relating to sustainability in building developments (Akadiri, 2011).

Before stakeholder influences on sustainability are investigated, stakeholder management in the construction industry must be discussed. Newcombe (2003) focuses on the importance of stakeholder mapping, to manage the evolution of their interactions and influences. This is due to the critical nature that "...the project's objectives mesh with it stakeholders, and that they continue to fit stakeholders' interests as the project evolves, conditions change and the interdependencies of key systems, stakeholder and their objectives change." (Newcombe, 2003). In the conclusion of this research paper, two key principles emerged. Firstly, the project should be managed for the benefit of all its key stakeholders (internally and externally), and their associated beneficiaries (e.g. employees). This includes inclusion in decision-making that affects their welfare. Secondly, the project manager must accept the fiduciary responsibility of the stakeholder relations. They must act as the custodian of the projects stakeholder network, and act in the interest of the stakeholders and the projects objectives (Newcombe, 2003). Once mapped, Yang et al. (2009) proposes 15 critical success factors (CSF) to help evaluate stakeholder management performance for design and

construction projects - refer to Table 7. A survey of 183 design and construction professionals was undertaken to identify the importance, and ranking of the 15 CSF. Evaluating stakeholder managing with reference to the proposed CSF's will help project managers make decisions based on aligning stakeholder and project objectives, further identify underlying stakeholder relationships, and identify areas of improvement.

Table 7: Ranking of CSF's (Amended, Yang et al. 2009).

CSF Rank	CSF Name
1	Managing stakeholders with social responsibly (economics, legal, environmental and ethical)
2	Exploring stakeholders' needs and constrains to projects
3	Communicating with the engaging stakeholders properly and frequently
4	Understanding the area of stakeholders' interests
5	Identifying stakeholders properly
6	Keeping and promoting a good relationship
7	Analysing conflicts and coalitions among stakeholders
8	Predicting the influence of stakeholders accurately
9	Formulating appropriate strategies to manage stakeholders
10	Assessing attributes (power, urgency, and proximity) of stakeholders
11	Compromising conflicts among stakeholders effectively
12	Formulating a clear statement of project missions
13	Predicting stakeholders' reactions for implementing the strategies
14	Analysing the change of stakeholders' influence and relationships during the project process
15	Assessing stakeholders' behaviour

Dair and Williams (2006) focused on understanding stakeholder influences in achieving sustainable outcomes for brownfield developments in England. The aim of this research was to evaluate brownfield developments and their elements and levels of sustainability objectives with respect to stakeholder type, influence and their level of sustainable consideration. For building development project, Dair and Williams (2006) concluded on five different, but key stakeholder groups important to the development process. The stakeholder groups and types are outlined in Table 8.

Table 8: Stakeholder Groups Involved in Building Developments (Amended: Dair and Williams, 2006).

Stakeholder Group	**Examples of Types of Stakeholders Within Each Group**
Stakeholder involved in land-use planning and regulation	
Group 1: Regulators, statutory consultees, services providers, and councillors.	Environmental agency regulators (e.g. pollution-control regulators, drainage and flood-defence regulators, biodiversity-protection regulators - DECC)
	Local authorities regulators (e.g. planners, urban designers, environmental-health officers, highways and transport regulators, landscape architects)
	Health and Safety regulators (WorkCover)
	Councillors
	Building Control (local authority or approved inspectors such as National House Building Council)
	Utility regulators and service providers (gas, electricity, water and drainage)
	Central government departments and regional authorities
Group 2: Non-statutory consultees, interest groups, and individuals	Business interests
	Pressure groups
	Community-group interests
	Individuals
Stakeholder involved in development and construction	
Group 3: Property developers and developer interests	Public sector and private developers
	Land owners
	Investors (e.g. developers, banks, pension funds)
	Construction workers
	Manufactures and Suppliers
Group 4: Professional advisors	Lawyers
	Architects, planning consultants, landscape architects, conservationists and archaeologists
	Civil, structural and environmental engineers
	Surveyors
	Insurers and cost planners
Stakeholder involved in end-use	

Stakeholder Group	**Examples of Types of Stakeholders Within Each Group**
Group 5: End User	Clients of developers (e.g. manufacturers, business entrepreneurs, retailers, home buyers, public-service providers
	Residents of dwellings and residential homes
	Proprietors of commercial business including offices, shops, and restaurants and their suppliers, employees and customers
	Managers and proprietors of public or private institutions including schools, hospitals, and leisure centres, and their employees and visitors.
	Landowners of public or private open space, parks, gardens, woodland and public that use those areas.

Dair and Williams (2006) found that the important decision makers, and stimulators for incorporating sustainability objectives into developments were building developers, clients and end users. However, the main catalyst for delivering sustainable objectives are building designers and architects, because they are the professional advisor responsible for achieving project outcomes outlined in the 'Clients' Brief' in alignment with planning constraints. From the evaluation of the five brownfield case studies, Dair and Williams (2006) conclude that the shortfalls in creating sustainable developments are due to five main factors.

Firstly, developing ineffective sustainable project objectives which stem from a lack of tangible guidance, not stakeholder willingness at the project initiation stage. Secondly, the timing of different stakeholder involvement during the development process, e.g. builder/contractor input is generally at the end of project planning and through to project completion, therefore limited input from the builder/contractor is given in the critical initiation and planning phase. Thirdly, the perceived absence of power of stakeholders to change and achieve sustainable objectives, although their desire to create sustainable outcomes is holistically evident across all stakeholder groups. Fourthly, the varied attitudes of stakeholders regarding the use of sustainable technologies and materials, especially that of whom stood to suffer the consequence of any underperformance and failure. Fifth and final factor is considered by Dair and Williams (2006) as the most fundamental, failing to understand what sustainability is and not having the ability to measure its successful implementation. Each stakeholder group may show a genuine aim for sustainability, "however, each stakeholder groups, and importantly, various types of stakeholders within each group, had differing ideas about whether 'success' has anything to do with sustainability.' (Dair and Williams, 2006).

Akadiri (2011) focused on developing a multi-criteria approach for selecting sustainable materials for building projects. This required a more micro approach to stakeholder influence and decision-making of materials to meet development objectives. Firstly, it was revealed that little was known about stakeholder involvement at this micro level of product selection. To gauge stakeholder influence, Akadiri (2011) conducted a survey of Architects and Building Designers, as they are the constraint variable and centre of decision-making for building materials. The respondents were asked to rank (from 1 to 5, with 1 representing low influence and 5 representing high involvement) the influence of different stakeholders with relation to material selection - refer to Table 9. ‘RI’ in this table represents the respective ‘Respondent Influence’ score, i.e. the calculated quantitative influence each stakeholder has on the Architect/Designer.

Table 9: Stakeholder Influence on Material Selection (Akadiri, 2011).

Stakeholder influence	Architects		Designers		Overall	
	RI	Rank	RI	Rank	RI	Rank
Client	0.75	1	0.76	1	0.76	1
Technical consultants	0.65	2	0.67	2	0.66	2
Quantity surveyors	0.58	3	0.60	3	0.59	3
Site Managers	0.57	4	0.57	4	0.57	4
Contractors	0.58	3	0.52	5	0.55	5
Project Managers	0.41	7	0.52	5	0.52	6
Product manufactures	0.47	5	0.41	6	0.44	7
Product suppliers	0.46	6	0.40	7	0.40	8
Test statistics						
Kendall’s W=0.328 x^2 *critical*(=0.05)=14.07; *df=7;* x^2 *sample=792.5*						

The 'test statistics' method was applied to the determined rankings in order to test the significance of the findings. The resulting ‘W Value’ was 0.328 (Kendall’s ‘coefficient of concordance’), which is significant at 95% confidence level, outlining a high degree of agreement between building designers and architects as to the ranking of stakeholder influence. X^2 represents the results of the ‘Chi-Squared’ significance test.

By nature, this result may be skirted to the actual influence rating of each group because the survey only considered building designer and architects. Therefore obtaining results from one

'type' of 'information pool'. The education, and services and integration into a project can be considered very consistent. The degree of stakeholder influence can also be greatly affected by the contractual structuring of the project, i.e. Project Managers/Contractor contracted as the 'Head Contractor', and therefore all other services (including building designers and architects) are reporting only to the head contractor.

3.2 Effective Decision-making Practices through Multi-Criteria Decision Analysis

The following section outlines the usefulness of effective decision-making practices, and evaluates current practices in sustainable development case studies.

3.2.1 Decision-making: Multi-Criteria Decision Analysis (MCDA)

Dair and Williams (2006) define multi-criteria decision analysis (MCDA) as, 'an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter'. This general statement outlines the three key dimensions of MCDA: Its formal approach, multiple decision criteria, and decisions are made either by individuals or groups of individuals. Moberg (2011) explains that MCDA has been anonymously successful because of its inherent properties that make this method practical and simple, and therefore appealing. The inherent MCDA properties '[Seek] to take explicit accounts of multiple, conflicting criteria, it helps to structure the management problem, it provides a model that can serve as a focus for discussion, and it offers a process that leads to rational, justifiable, and explainable decisions." (Moberg, 2011). The purpose of the MCDA method is to develop a relative view point for all eligible options with respect to essential decision criterion. MCDA is an 'options process' decision support tool, and subjects all options to a 'decision analysis', which comprises of four components: Option, Criterion, Alternative, and Attribute. A general classification of MCDA (Dair and Williams, 2006) (Levin, 1997), and all subsidiary decision-making tools to MCDA, is outlined in Table 10.

Table 10: Multi-criterion decision analysis methods: a general classification (Levin, 1997).

Multi-criterion decision analysis methods: a general classification.	
Goal, aspiration or reference level	Desirable or satisfactory levels of achievement are established for each criterion. The process then seeks to discover options which are closest to achieving these desirable goals or aspirations
Valuation	Numerical scores are constructed in order to represent the degree to which one option may be preferred compared to another. Such scores are developed initially for each criterion, and are then synthesised in order to effect aggregation into higher level preference models. Though in practice valuation is not applied in such a rigid framework, this relatively strong set of axioms (a) imposes some form of discipline in the building up of preference models, (b) assists greater understanding of the values used, and the justification of the final decision when required, and (c) encourages explicit statements of acceptable trade-offs between criteria
Outranking	Alternatives are compared pairwise, initially in terms of each criterion in order to identify the extent to which a preference for one over the other can be asserted. In aggregating such preference information across all relevant criteria, the model seeks to establish the strength of evidence favouring selection of one alternative over another

The research carried out by Moberg (2011) focused on evaluating the current MCDA methods, and their applicability and optimisation towards the forestry and natural resource industry. Due to the complexity of resource management, inherent lack of information, and multi-stakeholder involvement, Moberg (2011) only considered MCDA methods that consider a hierarchy of criteria – multiple objectives and alternatives. The forestry and natural resource industry could be likened to the built environment with respect to complex supply chains, regulations, and comparable multi-stakeholder involvement, additionally; the built environment needs to consider change in location and the theoretically infinite number of design options.

There are two main groups under the MCDA umbrella, each with their distinct differences and applications. The first is the multi-objective decision-making (MODM) and multi-attribute decision-making (MADM) (Moberg, 2011). The main distinction between the two groups of methods is based on the number of alternatives under evaluation. The MADM method is geared towards selecting discrete alternatives, while MODM is more adequate to deal with multi-objective planning problems, when a theoretically infinite number of options

are plausible (Moberg, 2011). Table 11 compares MADM and MODM methods with the selected decision-making criterion.

Table 11: Comparison of MODM and MADM approaches (Moberg, 2011).

Criteria for comparison	**MODM**	**MADM**
Criteria defined by	Objectives	Attributes
Objectives defined	Explicitly	Implicitly
Attributes defined	Implicitly	Explicitly
Constraints defined	Explicitly	Implicitly
Alternatives defined	Implicitly	Explicitly
Number of alternatives	Infinite (large)	Finite (small)
Decision maker's control	Significant	Limited
Decision modelling model	Process-oriented	Outcome-oriented
Relevant to	Design/search	Evaluation/choice

3.2.2 Decision Support for Sustainable Developments with Respect to the Three Themes of Sustainability

Traditionally, process support (like that found in project management) focused on constraint-based decision-making that only applied to financial and tangible objectives. In recent years more has been asked of decision-making professionals. There is a growing demand for decisions to be made around intangible objectives, such as environmental and social ones (Doloi, 2007). The heightened need for considering the intangible, the social and environmental aspects within a project has grown through greater understanding of evaluating holistic project success and failure. This has lead researchers and practitioners to evaluate and redesign decision-making processes, frameworks and tools with respect to their interaction, development, and enactment (Heemstra and Kusters, 2004). Intangible decision-making relies on a different set of inputs, frameworks, evaluation and outputs than the traditional, tangible decisions making tools. To develop the project management framework, the research will focus on both the tangible and intangible decisions, for economic, social and environmental factors, that need to be made during the project charter stage through to planning permission for the project. Kiker *et al.* (2005) outlines that the success of any

decision-making system within a complex setting will dependent on three key components: people; process and tools.

3.2.2.1 Environmental Decision-Making

Environmental decisions for sustainable developments are often complex, multifaceted and connected socially and financially. In most cases, such decisions are intuitively simplified to make the options, and therefore decision, more manageable. During this intuitively ad-hoc process, connectivity to social and financial aspects may be ignored, and 'information may be lost, opposing views may be discarded, and elements of uncertainty may be ignored.' (Kiker *et al.,* 2005). Currently, there is no systematic methodology to combine quantitative and qualitative inputs, with stakeholder preferences and consideration to social and environmental connectivity, that provides a value trade-off for different plausible alternatives during a project life (Kiker *et al.*, 2005).

A great number of decision-making support systems, regarding environmental and energy consumption aspects, for building developments have been based on the Life-Cycle Assessment (LCA) (Juan *et al.*, 2010). This can be attributed to the general acceptance of LCA within the environmental research community as a valid method to compare decision options with respect to materials, components and services (Cole, 1998). However, (Cole, 1998) outlines that the widespread adoption of the LCA approach will be limited because of its complex nature "…in [which] it involves the aggregate effects of a host of life-cycles of their constituent materials, components, assembles and systems. The ongoing efforts to enhance the LCA approach and data will be invaluable in the evolution of more applicable and comprehensive decision-making and sustainable rating tools (Cole, 1998).

As mentioned previously, the design stage during a sustainable development represents the key moment when influential decisions affecting the three themes of sustainability are made. There is now a considerable amount of design-relevant information relating to a various environmental issues, far more than that currently incorporated into sustainable rating tools (Cole, 1998). The adoption of rating tools has surpassed design best practices with owners, designers and builders because they represent an organised process which is understood to manage the most signification environmental issues (Cole, 1998). The complexity and

challenging application of LCA, the segregation of design best practices, and the inadequateness of sustainable rating tools as ‘design and decision-making’ tools provide decision makers for sustainable developments with haphazard guidance and unjustified information to support environmental decisions.

With every development, there are trade-offs and compromises that need to be made among various solutions with the aim to optimise building performance to various defined objectives (i.e. relating to environmental, social and financial) (Levin, 1997). As indicated by (Cole, 1998), the current approach for optimising design, with validated decisions to environmental objectives is debatable. (Levin, 1997) concluded that designers and decision makers need to be more aware of the wider environmental implication during decisions relating to project optimisation, as consideration of the global scale can adjust decision outcomes.

3.2.2.2 Social Decision-making

Social decision-making initiatives are outside the scope of this thesis. This is an area research of that could complement the decision-making process during the development of sustainable residential projects with respect to the greater social context (Akadiri, 2011).

3.2.2.3 Financial Decision-making

Financial decision-making was the first method use for evaluating project success. Cost-benefit analysis is a quantitative method to analyse economic rational during construction projects from the perspective of the key project sponsors (Ma and Ma, 2013). Furthermore, risk budgets were used to allocate project money in substitute of risk management. The financial success of most construction project is at the core of the projects objectives - providing a return for investors. With the momentum of sustainable development, investors have taken a similar cost-benefit approach, by balancing the potential future returns against initial, increased project outlay - including the sustainable rating tool assessment, and in most cases the public sector is being the industry champion (M. J. Warren, 2009).

Considering sustainable developments, it is difficult to find documented cases of applied financial decision-making against specific 'sustainable' alternatives. However, there are multiple cases where a cost benefit analysis was complete retrospectively. This could be due

to the inherent difficulty and additional efforts required by the project delivery team to comprehensively define solutions with respect to long term sustainable benefits. Nevertheless, all retrospective case studies were calculated based on the buildings the life cycle analysis (Gabay *et al.*, 2014, Martinho *et al.*, 2013, Josh Byrne & Associates, 2012).

Martinho *et al.* (2013) present a residential house case study that is based in Portugal. Within their findings, investing an additional capital expenditure of €29,285.20 would result in a payback period of 13 years, and over the 50 year time period a total saving of €51,616.82 - refer to Figure 20. Further details regarding the evaluation method used and results can be found in their research paper.

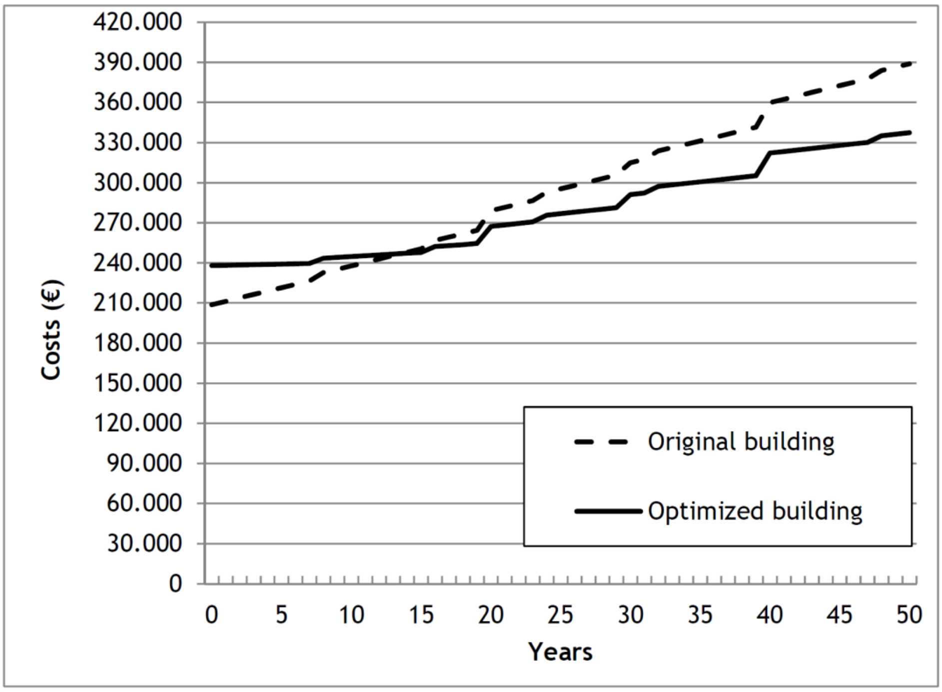

Figure 20: Cost-Benefit Evaluation - Portugal Case Study (Martinho *et al.*, 2013).

Josh Byrne & Associates (2012) undertook a similar project, they designed and constructed a residential house that is based in Perth, Australia. The aim of this house was to demonstrate that a typical Australian house could be constructed in alignment with current building rates, but still achieve a high level of efficiency and pay-back period. Figure 21 outlines that the payback period for this project is 7 years.

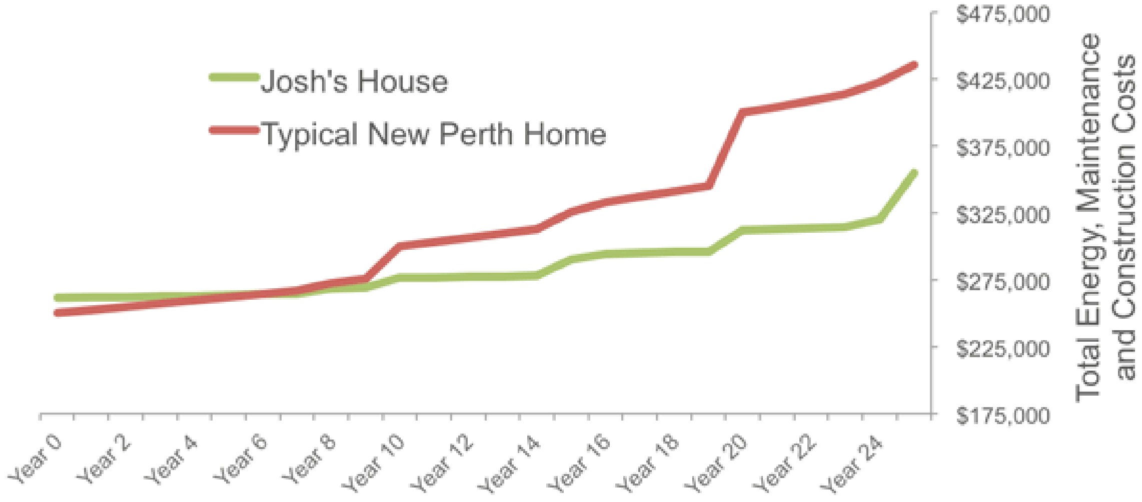

Figure 21: Cost-Benefit Evaluation - Australia Case Study (Josh Byrne & Associates, 2012).

3.2.3 Decision-making in Practice: Researched Case Studies

There are endless numbers of case studies that present their current achievements towards reaching ever-higher sustainable development objectives. Over the decades, sustainable development outcomes have evolved. Traditionally, sustainable development outcomes were focused on building operational energy, with research focusing on increasing energy efficiency. Over decades, the term 'sustainability' has become more holistic, and therefore priorities of the public, professionals and researchers have changed - allowing for a current, broader and richer pool of case studies relating to best practice in sustainable building.

This research will review and compare published research case studies and their contribution to 'sustainability' in terms of:

- What sustainable development objectives were targeted by the case study,
- The degrees of success for the targeted sustainable development case studies,
- Insight into decisions made during the case studies,
- If capable, a consideration of derived decisions to financial and social factors,

3.2.3.1 Aspects of life cycle investing for sustainable refurbishments in Australia (Hertzsch *et al.*, 2011)

This work by Hertzsch *et al.* (2011) focuses on reducing building operation energy by retrofitting building facades to help reduce the system load of HVAC systems, and also

retrofit options to in-situ HVAC systems. The retrofit options, and their improvement effects, were evaluated through 'Design Builder' simulations. In addition, the research compares the above retrofit options to financial investment factors. The key financial investment input data that are considered by (Hertzsch *et al.*, 2011) are:

1. Asset value at commencement and termination of the analysis period,
2. Life cycle investment in renewal of component assets such as HVAC systems at the end of their service life, and the like,
3. Income, and
4. Taxation of income and depreciation allowances available under the Australian taxation system.

The case study building in this research was based in Melbourne; the building was a 21-story office block, plus a 9 level car parking podium. Overall, nine simulations were conducted, three of which created the 'base case' (do nothing, maintain normal maintenance schedule) for the office building. The other six simulations represented different sustainable upgrades. The six sustainable upgrade simulations were divided into two groups, one for the Melbourne climate and the other for the Brisbane climate. The aim is to compare how climate effects the optimised retrofit option. The three simulations for each climate type were HVAC upgrade only, façade upgrade only, and a combination of the two.

Key Sustainable Development Objectives:

The key objective of this research is to investigate an appropriate methodology for realistic evaluation of retrofit options for reducing building operational energy. The aim was based on the following:

- Compare performance of retrofit options versus base case (normal maintenance schedule)
- Determine the effects different façade retrofit options had on HVAC energy use
- Determine the effects different HVAC retrofit options had on HVAC energy use
- Financially evaluate each proposed retrofit option (façade, HVAC, or façade and HVAC)

Method of Analysis:

The methodology used for analysis was developed by Hertzsch *et al.* (2011). This methodology divided the analysis of retrofit options into three stages. Firstly, 'system inputs', the inputs are collected from base building data, base building operational data, suggested retrofit options and investment data. Secondly, simulations were conducted against the different retrofit options. Each retrofit option has three simulations, 'building energy simulation', 'energy rating simulation' and an 'investment simulation'. The simulation tools used by Hertzsch *et al.* (2011) are:

- Design Builder (building energy simulations)
- NABERS (energy rating simulations)
- Net Present Value & Internal Rate of Return – over a 10 year period (investment simulations)

Thirdly, 'system outputs', each proposed retrofit option is compared with the information gathered from the three simulations related to each option. The flow chart of the methodology is outlined in Figure 22.

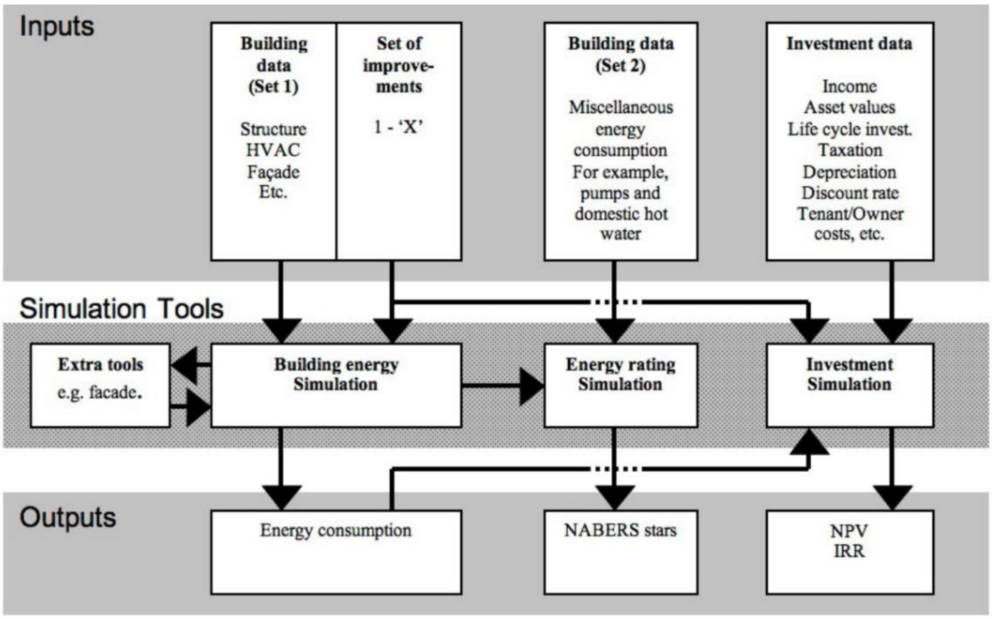

Figure 22: Methodology for simulation comparison (Hertzsch et al., 2011).

<u>Review of Decisions Made:</u>

The researched focused on making a decision around the most effective way of reducing operational energy demand on a base-case building in Melbourne. The sustainable objective was to reduce operational energy by façade upgrades and/or HVAC upgrades. The attributes for the decision-making process was based on:

- Building use
- Building attributes
- Location and climate
- Degree of operational energy reduction
- Life-cycle financial investment

3.2.3.2 Hybrid Decision Support System for sustainable and energy efficient office building renovations (Juan *et al.*, 2010)

Juan *et al.* (2010) propose an integrated decision support system (DSS) that considers adaptable sustainable practices with financial investment and quality for office renovations. The purpose for such a system was derived around the increasing energy demands associated with office space in developed nations, and their relatively quick renovation rate. (Juan *et al.*, 2010) believe this tool could provide a relatively fast (in sustainable development terms) and dramatic effect on the sustainability and energy of office space with this very pragmatic approach to decision-making. The DSS was designed with three major processes:

1. <u>Assessment:</u>
   Assess the 'sustainability level' of the current office building based on the criteria (criteria developed from LEED, BREEAM and GBTool System).
2. <u>Method and Strategy:</u>
   Provide renovation feasibilities by adopting a hybrid approach algorithm that analyses the trade-off between the preferred budget and expected improvement quality.
3. <u>Feedback:</u>
   Compare the different feasibility option with the original office building.

The first stage of the DSS requires assessment and rating of the existing building, possible sustainable renovation options (against sustainability criteria), cost and quality. Assessing and rating these options is achieved through a ‘question base assessment’, using qualitative and quantitative approaches, ‘Rule-Based’ (renovation contractors and building experts) and

'Database' (building database publications) respectively. A separate list of questions is posed to the project team for each sustainable criterion. Every question must be answered under each sustainable criterion, for each sustainable renovation option. Comparing and proposing the most optimal renovation solution, and sub-solutions is assessed using a combination of the genetic algorithm (GA) and A* algorithm approach. Juan et al. (2010) consider the hybrid GA and A* approach key to the success of the proposed DSS, as it allows for complimentary problem solving rom both methodologies. GA is regarded as an effective and optimising analytic tool for large and complex problems, while A* is a heuristic graph based methodology that optimises project path by considering project past, present to project completion. The DSS concept concludes with decision feedback and validation. The interrelation of these processes is clearly displayed in Figure 23.

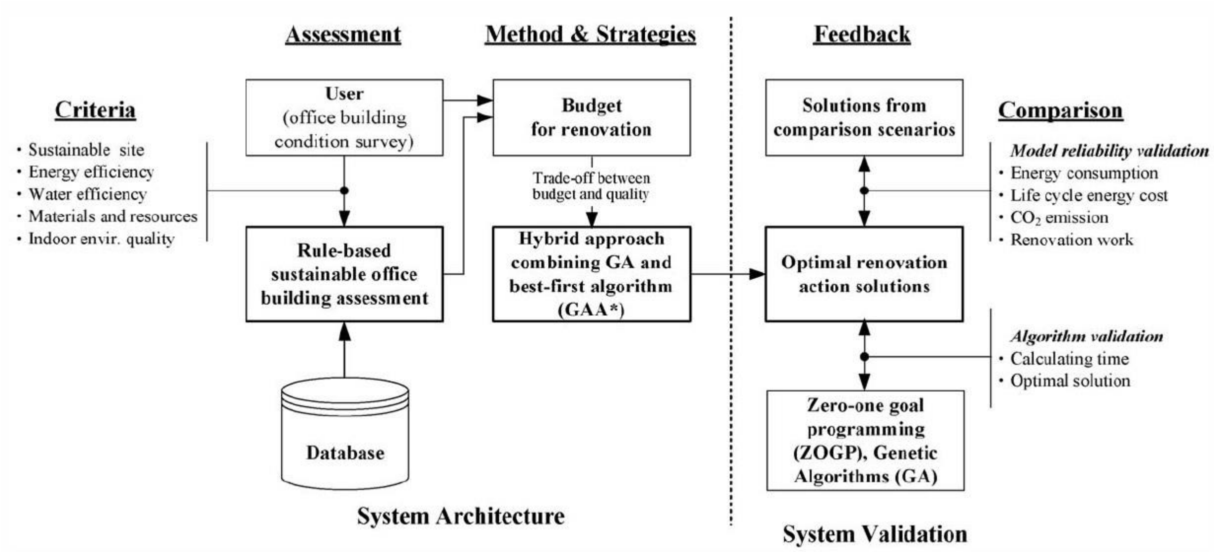

Figure 23: Architecture for DSS (Juan *et al.*, 2010).

The DSS system proposed by Juan et al. (2010) was demonstrated on the renovation of a disused wine storage building in Taiwan. The case study building was originally built in 1979 as a 2190m^2 storage warehouse for varieties of wine and beer. A change in social structure and privatisation of state-owned enterprise led the building to become obsolete in 1998. In 2004, the abandoned warehouse was recognised to have historic value with cultural heritage for the area; this led to its selection by Council of Cultural Affairs (CCA) for the sustainable urban regeneration plan.

The warehouse had many existing problems, such as unfavourable ventilation, inefficient appliance, unfit insulation in the external walls and roof, no waste management and insufficient greenery. The three level warehouse was renovated into an office space for $910,000 (US), and completed in 2005.

3.3 Chapter Conclusion

There is no doubt that the delivery of building projects is closely linked with the project management profession. Surprisingly, there is little research conducted on the effects of project management practices on sustainable developments - a greater focus is placed on sustainable rating tools. As outlined, PMBOK (PMI, 2008) is the leading literature in the project management profession, and has been used by several other researchers when compiling sustainable management practices. Eid (2003) and Robichaud and Anantatmula (2010) believe that the integration of sustainability (in the form of the triple bottom line) into the project management practices can greatly reduce the implementation costs of sustainable 'features', and deliver projects that a refined in terms of the triple bottom line. Recent, practical case studies validate the premise that a sound sustainable project management framework can delivery comfortable, efficient, and low impact houses.

To successfully create a sustainable development project management framework, it must learn from the lessons learnt from the other studies and work experience. As a start point, the framework should be based on the project management best practice - PMBOK guide. As identified, a tailored project risk management and stakeholder management, and instilling sustainable objectives are the key ingredient to ensuring an effective framework.

There is a significant amount of research in the area of decision-making. This is due to the influential nature of a decision, on overall project direction and successfulness. In the case of building developments, the decision-making process needs to adapt to the context of the decision, while remaining holistic for the overall success of the project objectives. Various research case studies have been presented to give context to the large array of decisions, in a catalogue of different areas, that need to be made during the design and construction of a building. As sustainable developments become more complex, making informed decisions becomes more difficult. Adequate information needs to be gathered, synthesised, and distributed to a large group of key stakeholders.

CHAPTER 4. RESEARCH METHODOLOGY: RESEARCH INTERVIEWS, PROJECT MANAGEMENT FRAMEWORK, CASE STUDIES AND VALIDATION

4.1 Introduction

This chapter sets out the research methodology, and highlights the approach taken to conduct the research interviews, develop the project management framework, implement the project management framework to case studies, and validate the case study results. When undertaking research, it is important to design a rigorous research methodology, to ensure that the research objectives can be met and the findings validated. Firstly, this chapter begins by presenting a list of research questions that were developed as a result of an analysis of gaps and weaknesses in previous work found during the literature review. Research methodologies were then evaluated and selected with respect to their merits and the research questions that required answering.

4.2 Research Approach

The literature review in Chapter 2 covered the sustainable development subject area, which encompasses sustainable building objectives, the 'triple bottom line' for sustainable development, life-cycle analysis, sustainable building rating tools, and case studies. The literature review in Chapter 3 covered the project management subject area, which encompasses project management theory (PMBOK), stakeholder management, risk management, financial management, monitoring and case studies. The literature review gave the presented author insights into the interconnected nature of project management and decision-making, and the influences these processes have on the successful delivery of project objectives.

The literature review opened up a number of research questions. The research methodology was designed to answer the following questions:

- What constitutes a project success or failure for an architect, designer, builder and client?
- How do architects and designers manage, through decision-making, project objectives?

- What perceived obstacles hinder the adoption of environmental practices?
- Who are the principal stakeholders in the development of a house, and what influence do they have in developing building specifications (e.g. materials, details, etc) and overall project delivery?
- How do architects, building designers and builders justify or promote 'sustainable practices' to their clients'?
- What are the key project risks, how are project risks managed, and who is responsible for mitigating or avoiding these risks?
- What are the current sustainable building assessment techniques used by residential building professionals?
- How are financial, social and environmental considerations managed?

4.3 **Review of research methods**

Research is the pursuit of greater understanding or discovery, and requires *"...a systematic examination to discover new information or relationship, and to explain/verify existing knowledge for some specified purpose."* (Bennett, 1991). Research design is the logical sequence that enables the gathering of data, analysis and ultimately the means by which one can draw conclusions, with the aim of answering the initial research objectives of the project or program of work (Yin, 2009). In terms of management research, Veal (2005) believes that *"There is considerable debate regarding the nature of management research [because of] the little consensus concerning its definition."* Clegg et al. (1999) suggests that the nature of management is much more complex than just an understanding of making processes or resources allocation more effective. It is argued that management takes the form what whatever it 'needs' to be to achieve a goal within a certain social context. Therefore, management research or management theory is only as valid as the specified research method and context in which the research was conducted. One model of the general research design process that researchers embark on is illustrated in Figure 24.

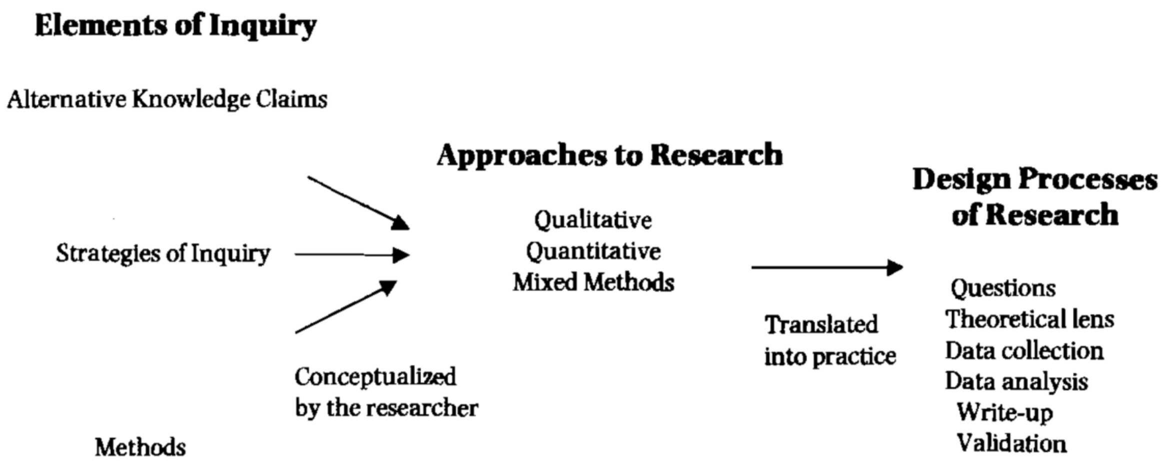

Figure 24: Research Design Process (Creswell, 2013).

There is a wide array of research methods, each designed for a specific use individually or in combination to elicit specific responses for particular research conditions (Veal, 2005). Yin (2009) suggests five research groups:

1. Experiment;
2. Case Study;
3. Survey;
4. Archival Analysis; and
5. History.

Each research group is defined individually by three research methods (Veal, 2005),

1. *Descriptive Research:* Finding out, describing what is.
2. *Explanatory Research:* Explaining *how* or *why* things are as they are (and using this to *predict* demand, sales, impacts, etc.).
3. *Evaluative Research:* Evaluation of policies, strategies, programs and practices.

These various research methods and groups fall into two classical distinctions, either qualitative or quantitative research methods, and the combination of the two is termed a triangulation approach (Veal, 2005). The following sub-sections provide a brief description of these research methods.

4.3.1 Quantitative research

Quantitative research, or empirical research, is where data is in the form of numbers or measurements (Punch, 2013). Creswell (2013) definition of the quantitative research '...approach is one in which the investigator primarily uses post-positivist claims for developing knowledge (i.e., cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data.'

Generally, this approach is best suited to large quantities of research data, which computers are needed to analyse. To enhance reliability of numerically analysed results, it is often necessary to capture as much data as possible under controlled conditions (Veal, 2005).

4.3.2 Qualitative research

Qualitative research is the method and technique used to generate qualitative information. The term qualitative describes information that explains a 'phenomenon in the social world' (Veal, 2005). Qualitative research requires the interaction with people who are suitably qualified or considered experts in the relevant area in which the research questions are based. The selected individuals are best placed to provide a description and analysis of the phenomenon in their own words. More specifically, qualitative research consists of detailed descriptions of events, i.e. context, behaviours, general opinion and what it *means* to people (Maxwell, 1992).

Huberman and Miles (2002) described qualitative methods as an ongoing, iterative process which comprises of four components (as shown in Figure 25):

- Data Collection: The collection of data from a given research method/s.
- Data Reduction: This is the process of extracting, selecting, simplifying and transforming of data.
- Data Display: This is the display of raw and/or reduced data in an organised format for interpretation and conclusions
- Conclusions: Refers to the conclusions drawn from the displayed data. In addition, it highlights the validity and limitations of the conclusions.

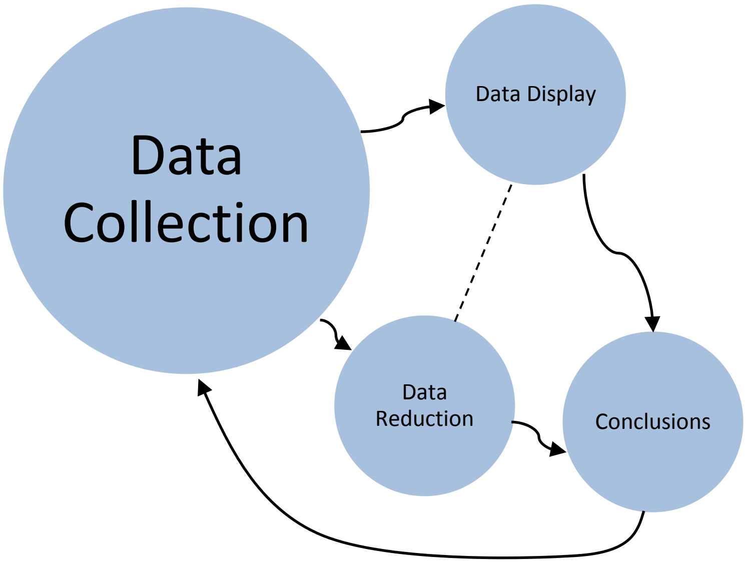

Figure 25: Qualitative Research Components.

Veal (2005) lists several qualitative research methods, and advantages to qualitative data collection.

Qualitative Methods:

- In-depth Interview
- Group Interviews/Focus Groups
- Participant Observation
- Analysis of Texts

Advantages and disadvantages of qualitative methods include the following:

- Allow researchers to understand in detail the personal experiences of individuals.
- Enables researchers to gather a 'richer' perspective of the context through different participants perspectives.
- Allow researchers to identify research issued from the participant’s perspective.
- Qualitative research can make presenting information more understandable and interesting to readers not trained in statistics.

4.3.3 Triangulation

Within the research circumstance, the term 'triangulation' means '...involv[ing] the use of more than on research approach in a single study to gain a broader or more complete understanding of the issues being investigated.' (Veal, 2005). This 'craze' began over forty-five years ago when scholars in the social science fields were racing to find ever more accurate ways to validate their work while remaining objective and sensitive to internal and external threats to the reliability of their results (Denzin, 2010). The development of the triangulation notion gave birth to the 'mixed method' research era - combining both qualitative and quantitative into one study (Denzin, 2010). This now established method of research offers researchers greater flexibility and confidence in validating their work when using multiple research methods (Torrance, 2012). For best outcomes, the combination of qualitative and quantitative methods needs to be tailored for each research condition, this will ensure a tailored matching of one another's strengths and weaknesses (Veal, 2005). Denzin (2010) proposed four different types of triangulation methods:

- Multiple methods: This method is a triangulation between methods and within methods;
- Multiple investigators: This research approach is undertaken through partnership or by teams instead of a single individual;
- Multiple data sets: This is the gathering of different sets of data through the use of the same method but at different times or with different sources;
- Multiple theories: This method can be used in a single research project.

4.4 **Adopted research methodology**

There is no 'hard-and-fast' method for selecting the best research approach, as the form of each research project is different in context, research aims and objectives. Generally, the research method chosen depends largely on the research aims and objectives, and therefore the questions that need to be answered through a tailored research methodology (Yin, 2009). Because of the board scope and complexity of this research, a wide range of research methods have been considered. This research has employed both qualitative and quantitative research methods in answering the research question and multiple methods of triangulation was used in evaluating the implementation of the project management framework on the research case studies.

The specific methods used in answering the research questions were:

- Research Interviews: research interviews were conducted on architects, building designers, builders and clients;
- Case Study: The case study methods was used to implement the sustainable residential development project management framework;
- Life-Cycle Analysis: Determine the overall carbon impact of the residential development against a national benchmark and the equivalent Building Code of Australia (BCA) design.
- Energy Modelling: Evaluate the overall thermal performance (heating and cooling demands) of the as-built residential development and the equivalent BCA design against the nationally recognised performance benchmark (NatHERS).
- Water Analysis: Evaluate the percentage of treated and town potable water used by each residential development case study against building code requirements.
- Financial Analysis: Determine the cost break-down for each residential development case study

4.4.1 Research Interviews

Research interviews are one of the most widely adopted method for social sciences, it effectively provides a description a phenomenon in the interviewees own words, which in some cases can be used as a representative sample of the given area of research (Akadiri, 2011, Veal, 2005). Understanding the background and characteristics of the potential interview participants is very important, and which is critical when designing an interview structure that successfully answers the research questions. An effective interview structure, with targeted questions will provide fuller, more detailed and accurate responses from participants, but can also produce exaggerated results by the participant wanting to please the interviewer (Veal, 2005). The interviews conducted for this research project were critical in gaining strong qualitative description of trends, attitudes and opinions currently prevailing in the sustainable residential design and construction industry. The qualitative information was an important aspect in shaping the project management framework.

4.4.1.1 Interview Development

The interviews conducted for this research were face-to-face and predominantly comprised of open-ended questions (respondents record their views and opinions in full). The success of the interviews, with answering the research questions, was dependent on the content, structure and response layout. Therefore, the survey must (Veal, 2005):

- Have clear and easily understood questions
- The questions should be structured to 'flow' from one to the next, while covering the core survey topics
- Fluently administered by the interviewer
- Responses easily and accurately documented, with the ability to edited and compiled for analysis

Akadiri (2011) utilised semi-structured interviews with industry professionals to develop a multi-criteria approach for the selection of sustainable building materials. Due to the similarity in research questions, the semi-structured interview approach was adopted on Akadiri (2011) method. However, the present author formulated the interview questions and structure based on finding from the literature review in Chapter 2 and Chapter 3.

The survey was divided into three main sections, for logical recording, analysis and reporting.

- <u>Sustainability Awareness & Adoption.</u> This section was designed to gauge the level of sustainability awareness and attitude within the industry from different points-of-view (architect/designer, builder and client). Obtain views on current adoption and implementation methods for sustainable practices in the industry. Investigate the basis for stakeholders' management approach and decision-making techniques - with respect to the level of importance placed on decision-making factors.
- <u>Application of Sustainable Design and Construction Principles.</u> This section explores the concept of sustainability, sustainable design and construction best practices, perceived barriers, available tools, and available information. Questions were also asked based on the implementation, management and decision-making techniques with respect to achieving sustainable objectives.
- <u>Influence that Project Management & Decision-Making has on Delivering Sustainability Outcomes:</u> Questions were asked to understand the perception that management and key decisions had on influencing successfully delivering of

sustainable developments. This section also helped present the different points-of-view among the interview participants, and used to highlight key focus areas for the development of the project management theory.

4.4.1.2 Interviews: UOW Ethics Approval

All of the interviews carried out over the course of this research were done so in accordance with the University of Wollongong (UOW) HREC Ethics Approval (Ethics Number: HE14/296 - refer to APPENDIX B: UOW Ethics Approval Letter) which was received on the 17 July 2014. The following information was sent to each potential participant (refer to APPENDIX C: Participants Invitation Letter, APPENDIX D: Participant Information Sheet, APPENDIX E: Interview Questions, APPENDIX F: Participant Consent Form)

- Invitation Letter
- UOW Consent Form
- Participant Information Sheet (PIS)
- Interview Questionnaires

4.4.2 Case study

In general terms the aim of a 'case study' is to comprehensively and accurately describe the example situation in question. The objective being to demonstrate and/or confirm a theory or raise doubts about it (Veal, 2005). Yin (2009) explains that a case study is a substantive method for validating research questions in their own right. The case study method is not intended for developing broad conclusions or universal representations, and therefore should not be considered in this context. However, case studies present general propositions relating to theories and policies between similar cases - this is no more evident than in the context of business and behaviours (Veal, 2005).

The case study method was chosen for this research project because the method offers the best means to explore the relationships and dependencies between sustainability, project management and decision-making for delivering sustainable houses. They will offer an empirical investigation into the real-life context of design and building that is too complex for surveys or experimental approaches. The case studies will help validate and propose limitations or shortfalls with delivering sustainable residential developments.

4.4.2.1 Case study Selection

The case studies in this research offer the opportunity to obverse the delivery of two sustainable homes, from the first-person perspective. The present author was directly involved in every step of the process, from the development of the *Design Concept* to *Practical Completion* of the building and building handover to client. Both case studies were designed and project managed the present author, acting on behalf of the consultancy company 'Progenia' (a trading name of Redson Group Pty. Ltd.). They were selected based on the following criteria:

- Building owner/client passion for sustainability and willingness to contribute to the research;
- Project alignment with research deliverables;
- Timing with research progress;
- Flexibility to adopt and apply the project management sustainable development framework (main research deliverable).

4.4.3 Performance Tools: Validating Sustainable Objectives

The building industry has generally accepted that incorporating sustainable rating tools into their developments will help them deliver sustainable developments (Cole, 1998). The use of sustainable rating tools has become more prominent, and cannot be ignored. However, their adoption may not be the true path to delivering and validating sustainable outcomes, as their interaction between the building construction and the environment is still largely unknown (Akadiri, 2011).

The history of the sustainable rating tool originated internationally, with the introduction of BREEAM (Building Research Establishment Environmental Assessment Method) in 1990 by the Building Research Establishment (BRE) (BRE Group, 2014), followed by the release of LEED (Leadership in Energy and Environmental Design) in 2000 by the US Green Building Council (USGBC, 2014). A rating tool did not arrive in Australia until 2003, it was developed based on the US LEED system, and created by the Green Building Council of Australia - the tool was named Green Star (GBCA, 2014). The latest iteration of the sustainable rating systems is the Living Building Challenge, launched in 2006 by the International Living Future Institute (2014). There are several other rating systems used

around the world, with their origins built around a similar premise (Iyer-Raniga and Wasiluk, 2007).

Sustainable Building Rating Tools focus on designing and evaluating a building against environmental criteria, which are spread across varying areas. For example: management; materials; water efficiency; energy efficiency; indoor thermal comfort; transport; etc. Generally, sustainable rating tools do not include financial considerations in the evaluation criteria (Qian and Xin, 2009).

Research has shown that sustainable buildings, certified to LEED and Green Star are more expensive to design and construct, but generally cheaper to operate – reduction of operation costs (water and energy savings) are difficult to compare due to the variation in rebates in different governments, locational factors and service providers schemes (Kato and Murugan, 2010, Nyikos et al., 2012). Kato and Murugan (2010) revealed that on average, Green Star buildings have a NABERS rating (National Australian Building Environment Rating System) of 4.8 (out of 5) for energy and 4.0 for water, with the Australian average for energy and water being 2.5. In addition, 50% of Green Star projects exceeded energy efficiency requirements, 16% performed on target, and 35% did not achieve their expected energy efficiency targets. Nyikos et al. (2012) have similar findings, with 36 of the 160 LEED buildings receiving no energy reduction benefits. Delivering reductions in operational expenditure, for initial capital outlay must be monitored and a balance of the three themes of sustainability, otherwise we cannot accurately justify the additional capital expenditure.

Kato and Murugan (2010) found that Green Star projects, on average attract an increase in capital cost of: 4 star projects attract an increase 12%, 5 star projects attract an increase of 10%, and 6 star projects attract an increase of 17%. It was also identified that 12% of green star projects were subject to no additional capital cost, while 10% of projects experienced an additional 35% in capital expenditure. This variation could be concluded to the star level that was trying to be achieved (not expressed in Kato and Murugan (2010) report), and the type of building, experience of the persons involved, and the project management of the buildings execution.

Generally, buildings certified to the LEED rating tool attract a cost premium. Associated research placed the low end of this premium at 1%, with a high end of the premium at 10.3% (Nyikos et al., 2012). Like Kato and Murugan (2010), Kats et al. (2003) reported a varying capital expenditure over the difference rating tool levels – Level 1 (Certified) is a 0.66% increase, Level 2 (Silver) is a 2.11% increase, Level 3 (Gold) is a 1.82% increase, and Level 4 (Platinum) is a 6.5% increase. Of the 160 LEED building sample, only 5 had an additional cost premium greater than 10%, with 1 having the maximum of 27.4%. This lower percentage average then Green Star could be accredited to the difference in two systems (environmental criteria and their weightings), and the increased number of accredited LEED buildings – potentially allowing for an increase is skill and experience of the persons to achieve the required LEED level.

In addition, Nyikos et al. (2012) concluded that there was no accurate method of validating initial capital expenditure to building performance with the available case studies as there are too many variables in the design and construction of a building that need to be considered, with limited available information. The two analyses between initial capital expenditure and operational saves, and other environmental features like internal air quality and natural daylight, are conducted in hindsight – trying to uncover relationships and trends. Therefore, incorporating the financial aspect of sustainability into the decision making process is a critically important evolution to ensure capital costs are justified and add measureable value to the sustainable development.

As discussed, there is currently a range of rating tools to assist in the assessment of buildings at various stages of the development process - i.e. concept, design, planning, construction and operation. A review of common sustainable rating tools can be found in APPENDIX A: Summary of Sustainable Rating Tools. Each country enforces their minimum building standard, in Australia this refers to the National Construction Code (NCC) (Australian Building Codes Board, 2015), which relies upon Australian Standards and BASIX requirements - within New South Wales (NSW) (Planning and Environment, 2014) to standardise performance requirements. To the lack of sustainable rating tool in the Australian residential market, and the outlined limitations of the tools motioned above. This research needed to adopt a specific arrangement of validation methods to evaluate and validate the delivery of sustainable residential developments.

BASIX was not used in the evaluation and validation of the project management framework, as it outlines the lowest standard for environmental requirements in residential developments in NSW (Building Designer 1, 2014). However, information from BASIX, NatHERS protocol and star rating matrix were adopted and evaluated using DesignBuilder.

4.4.3.1 BASIX

BASIX was first introduced by the NSW government to the Sydney metropolitan market on the 1st July 2004, with the aim of delivering equitable and effective water and greenhouse gas reductions across the NSW housing sector (Planning and Environment, 2014). BASIX is a planning tool, which assesses how a new, or large alteration, development will perform against defined sustainability indicators with the aim of reducing development water consumption and greenhouse gas emissions compared to the benchmark average (Iyer-Raniga and Wasiluk, 2007). The NSW government has set 40% target reductions on new and large alterations (Planning and Environment, 2014).

A BASIX certificate become mandatory for all new and large alteration develops across NSW on the 1st July 2005, and must be attached with the development application when it is processed (Iyer-Raniga and Wasiluk, 2007). Within BASIX a large alteration is a construction cost of more than $50,000. To obtain a BASIX certificate, the development must deem to satisfy requirements for building solutions in NSW. This process costs $50, and requires the user (generally the building designer/architect) to input the data relating to the residential development (location, size, building materials, mechanical systems, ventilations, window openings, energy sources, etc) into an online system.

In March 2009, the BASIX thermal comfort section aligned itself with the NatHERS 2nd generation modelling software (Planning and Environment, 2014).

4.4.3.2 National Housing Energy Rating Scheme (NatHERS)

"NatHERS encourages energy efficient building design and construction by providing a reliable way to estimate and rank the potential thermal performance of residential buildings in Australia." (Department of Industry, 2014)

The NatHERS scheme was introduced on the 1st January 2003 by the Australian Building Codes Board (Department of Industry, 2014). This rating scheme is a method of determining a building's thermal performance (annual heating and cooling loads) for residential houses in Australia. Once the thermal performance of a house is determined, the development is benchmarked by associating the performance to a 1 to 10 star scale (1 star representing a low thermally performing house, and 10 stars representing a high thermally performing house). Depending on the state or territory, different star ratings are mandatory. Currently in South Australia a minimum of 6 Star performance is mandatory, whereas New South Wales only requires a minimum mandatory standard of 4 stars.

NatHERS relies on a energy modelling protocol, accredited software packages, and certified practitioners to determine house heating and cooling energy demands. The three accredited software packages are AccuRate, BERS Professional and FirstRate (Department of Industry, 2014).

DesignBuilder

DesignBuilder is an advanced energy, thermal modelling, hot water and HVAC modelling tool that provides a graphical user interface. DesignBuiler also allows for the importing of 3D architectural models from ArchiCAD, REVIT or Microstation. DesignBuilder has recently released their latest version, v4. The latest version operates with EnergyPlus v8.1 and is compliant to be used for LEED, ASHRAE 90.1, UK compliant and Australia compliant (for the evaluation and reporting required for the BCA, Section J report) (DesignBuilder Software Australia, 2014).

Although the DesignBuilder website states a large amount of versatile and powerful tools, Manke et al. (2013) explains that the typical usage for DesignBuilder is to "…evaluate façade options (with respect to operation, climate zone and HVAC options), natural day-lighting analysis, solar shading, thermal simulation of natural ventilation, and sizing of HVAC equipment and systems." DesignBuilders interface intends to simplify the inputs and user display of a complex simulation program In addition, the software allows for the importing of multiple DXF and PFD 2D files, which allowed for the easier creation of large and complex buildings. These key features make DesignBuilder a powerful and accurate tool for assessing building fabric, shadowing and HVAC requirements (Manke et al., 2013).

4.4.3.3 Life Cycle Analysis (Ecospecifier, LCA Design & eTools)

Life Cycle Analysis (LCA) tools have been in the front-line for evaluating the total environment impacts over the life of the building (Cole, 1998). Cole (1998) explains that the theory of LCA, with standardised protocols, boundary conditions and reliable data will see an evolution in our understanding of the impacts our built environment represent. Numerous LCA studies indicate that the operational energy of a home is the greatest contributor, however the easiest to reduce through insulation and technical solutions (Thormark, 2002, Fay et al., 2000, Dahlstrøm et al., 2012, Hammond and Jones, 2008). Each LCA case study were derived using first principles around defined system boundaries, collected life-cycle inventory data, energy modelling data and the ISO 14040 to ISO 14044 LCA framework. Within recent years in Australia, three tools have been developed to make the process of LCA evaluation accessible during the design stage - allowing for the key decisions to be made during the design, and not retrospectively.

eTools

eTools was launched in 2010, is an intuitive, open-use, web-based whole of life cycle assessment and design tool. The focus of eTools was to provide a user-friendly tool for designers to evaluate designs, make decisions and provide comprehensive reports that are compliance with international standards ISO 14044 and EN 15978 - Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method (eTools, 2014). An LCA evaluation and recommendations for building project can be completed and verified by eTools, or by an outside user can input the data and eTools provide the third party review of the input data (eTools, 2014).

Life cycle analysis require system boundaries, eTools normal boundary conditions are an extension to the accepted EN 15978 system boundaries. eTools can also incorporate the impact of transport of construction labour, remaining operational energy (i.e. not included by EN 15978, this includes: computers, entertainment units, kitchen appliances, laundry appliances, miscellaneous appliances, etc), and the contribution of reuse materials, material recover, material recycling and exported energy (e.g. excess from PV systems) on the whole-of-life assessment. eTools has the ability to produce reports base on both boundary conditions. Figure 26 demonstrates the difference in boundary conditions.

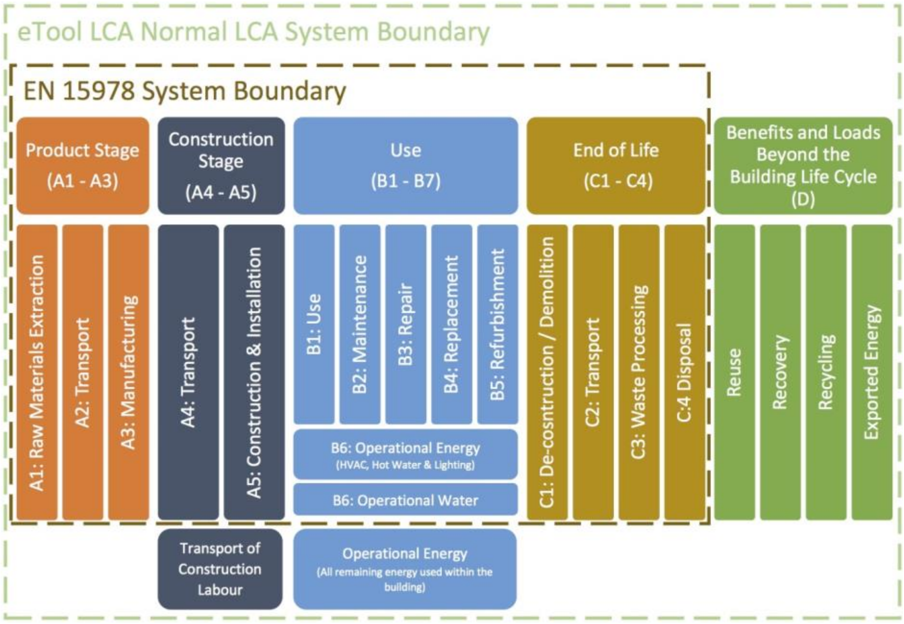

Figure 26: Comparison of eTools LCA Normal Boundary and EN 15978 System Boundary (eTools, 2014).

4.4.3.4 Water Analysis

A water analysis is the evaluation of potable water supply and water demand for the building development. For this research, the water analysis calculations were conducted using first principles. The water demand was calculated using assumptions based on: number of occupants; number of water points; water point flow rates; and frequency of use. Validation of case study water demand results were conducted by comparing average residential water usage results published by Sydney Water (2013). The supply of potable water, for both case studies, is from treated rainwater and town water. The annual quantity of treated rainwater used was calculated by rain data collected from the University of Wollongong rain gauge (Bureau of Meteorology, 2014), the roof area, roof pitch and quantity of rain storage. The annual quantity of town water supply was calculated by the water demand during periods during the year when the rain storage was 0.

Note, grey and black water should also be considered in the water analysis. However, for the research case studies, no treatment method was implemented.

4.4.4 Research Road map

The research road map outlines how each aspect of this thesis contributes to achieving the aim and objectives set out by the research purpose - refer to Table 12.

Table 12: Research Road Map

Research Aim:

The aim of this research is to define and develop a project management framework that will aid in the delivery of successful residential developments that result in a strong economical, social and environmental sustainability outcomes'.

PHASE	OBJECTIVES	TASK	METHOD	OUTPUT
Review	Investigate sustainable development implementation	A review of related research in the field.	LR	Chapter 2
		Review the historic context of sustainable development, from inception to its evolution to current day practices.	LR	
		Determine key sustainable development objectives for benchmarking residential houses.	LR	
		Review of current sustainable rating tools used to evaluate the environmental impacts of design and construction of buildings.	LR	
		A review of the Solar Decathlon competition.	LR, A	
	Investigate project management current best practices for delivering building developments	Review the origins and concept of project management.	LR	Chapter 3
		Examine project management best practices. The PMBOK Guide	LR	
		Suggest approaches for successfully integrating project management methods into the delivery of sustainable developments.	LR, A	
	Suggest ways to improve conventional decision-making methodologies and tools.	Review of quantitative and qualitative decision-making methods.	LR	Chapter 3
		Examine advantages and limitations for each decision-making methods.	LR	
		Suggest approaches for successfully integrating sound decision-making methods into the delivery of sustainable developments.	LR, A	
Synthesis	Investigate the general public's awareness of sustainability in Australia.	Prepare a survey questionnaire to undertake a review of the Australian general public's sustainability awareness.	I	Chapter 5
		Gauge the public's understanding and expectations when commissioning a sustainable home.	LR, I	
	Investigate sustainability awareness for architects, designers and builders and how it influences their management of projects and decision-making.	Prepare an interview questionnaire to gauge Australian architects, building designers and builder's awareness of sustainability.	I	
		Gauge the industries response to successfully delivering sustainable residential buildings.	I	
		Determine the principle methods currently used to deliver and verify sustainable residential developments.	I	
		Present and discuss the conceptual structure for the 'sustainable development project management' framework.	A	
Application	Develop a sustainable development project management framework for the residential market	Discuss the development, sCOPe and limitations of current approaches in ascertaining sustainability within buildings	A	Chapter 6
		Present a concept management framework for delivering sustainability within residential developments	A	
	Validate the SDPM framework through case studies.	Apply the SRDPM framework to real life case studies	CS	Master Level Thesis
		Validate case study finding and results.	LCA, EM, FA, WA	

LEGEND: A (analysis), CS (case study), I (interview), LR (literature review), LCA (life-cycle analysis), EM (energy modelling), FA (financial analysis), WA (water analysis)

4.5 Summary of research method

This chapter outlined the adopted research methodology to successfully carry out the present research project. The research methodology was developed with reflection on the findings outlined in Chapter 2 and Chapter 3. The literature review presented limited information for delivering and validating successful sustainable housing projects using project management practices.

The next three chapters action the research methodology. Chapter 5 consists of the research interview with design and construction professionals and residential clients. Chapter 6 presents the developed project management framework for delivering sustainable residential houses and Chapter 7 presents the findings from the application of the framework against two case studies.

CHAPTER 5. STAKEHOLDER PERCEPTIONS OF SUSTAINABLE RESIDENTIAL DEVELOPMENTS: SUMMARY OF INTERVIEWS

The aim of this chapter is to gain a greater understanding of the sustainable residential design and construction industry in Australia. This requires an assessment of the current status of the industry, notable trends, and the present awareness and implementation of sustainability amongst the key industry stakeholders. The methods used to address the chapter objectives is a combination of literature review - highlight the context and trends of the Australian design and construction industry, and semi-structured interviews with the key industry stakeholders to address sustainability awareness and implementation. The chapter will conclude by addressing the chapter objectives that are outlined in Table 13.

Table 13: Chapter 5 Research Objectives.

OBJECTIVES	TASK
Investigate the general public's awareness of sustainability in Australia.	Prepare a survey questionnaire to undertake a review of the Australian general public's sustainability awareness.
	Gauge the public's understanding and expectations when commissioning a sustainable home.
Investigate sustainability awareness for architects, designers and builders and how it influences their management of projects and decision-making.	Prepare a survey questionnaire to undertake a review of Australian architects, building designers and builder's sustainability awareness.
	Gauge the industries response to successfully delivering sustainable residential buildings.
	Determine the principle methods currently used to deliver and verify sustainable residential developments.

5.1 Interviews

An interview methodology was chosen for this chapter, to achieve several of the research objectives, and implemented as semi-structured interviews, conducted with an open-ended questionnaire. This method has proven to be effective in similar research contexts (Akadiri, 2011, Veal, 2005), and has helped to gather perspective for each interviewed stakeholder (and interviewee categories), and assisted in qualifying the researchers representative sample.

The participating interviewees were separated into two categories, professionals and clients. The professional interviewees were further separated into architects/building designers and builders. Each category had separate interview questions, pertaining to their perspective of the commissioning process.

The structure of the interview questionnaires was important to effectively address the objectives of this research. The interviews captured interviewee responses regarding their understanding of sustainability, how it was/is implementation (considered best practice) and the project management practices use to deliver residential developments. To most effectively achieve the objectives, the questionnaires were separated into four main topics, and interconnected between the two categories. The two categories are professional and client, and the four topics are:

- Sustainability & Project Overview

This topic was used to gather an understanding of the interviewees knowledge of sustainability. For the professional interviewees, they were asked additional questions regarding how projects are managed in terms of: project risks, successes and failures, stakeholder management and hindrances to implementing sustainability. For client interviews, each client was asked how their project was managed and why this method was adopted. The client interviewees were also asked if there were any unforeseeable outcomes during the commissioning process of their sustainable home.

- Social

Assessing social impacts is inherently difficult in sustainable building development because it has a broad community context. From the perspective of the interview questions, this topic asked the professional interviewees how social requirements for their clients are collected, managed and verified. The client interviewees were asked how their requirements were captured, and how well they felt their requirements were implemented.

In addition, this topic asked all interviewees how decisions were made, who was involved and when they feel certain stakeholders should be included in the decision-making process.

- Financial

The financial topic asked professional interviewees how they manage project budgets, variations/overruns, financial decision-making and contracting between the various stakeholders (and why). The client interviewees were asked how their budget was managed, the success of this financial management, what contracting between stakeholders were used and how they felt variations/overruns were managed.

- Environmental

The environmental questions asked professional interviewees how they presented, justified and validated 'sustainable features' to their clients. In addition, it asked what performance metrics were used by professionals to measure overall development performance. The client interviewees were asked how sustainable features were presented to them, and how important was their justification and validations by the relevant professional.

5.1.1 Ethics Approval

As mentioned in 4.4.1.2. ethics approval was obtained for the interviews. Details of this and the relevant documentation can be found in Appendices C,D,E and F.

The interviewees were separated into two categories: professionals (designers and builders), and clients (with research case studies and without research case studies). The issued PIS requested a 45 minute interview time for potential professional interviewees, and 20 minutes interview time for potential client interviewees. After the interview, the researcher prepared a written summary (refer to APPENDIX G: Interviewers Reports) which was issued to each respective interviewee for review and approval - if no response was received by the researcher, follow-up emails were issued.

5.1.1.1 Interview Response rate

Of the 7 survey requests to building professionals, 4 responded and agreed to the take part in the research. This creates an acceptance of 57%. Of the 6 survey requests to key stakeholders (the client), 4 responded and agreed to take part in the research. This creates an acceptance of 67%.

5.1.2 Summary of Interviews

The summary of interviews outlines the respective pseudonym, date of interview, recruitment of interviewee and the relevant background of each interviewee. Client 1 and 2 were part of the action research element of the sustainable development project management framework. Client 3 and 4 were not part of the action research, however chosen because they sought to development sustainable homes and did so using ‘traditional’ methods/industry practices.

This allowed the researcher to gain a perspective of how clients have undertaken the commissioning of their sustainable homes. The interviews conducted for this thesis are listed in Table 14.

Table 14: Summary of Interviews.

Participant & Pseudonym	Interview Date	Recruitment	Business & Participant Characteristics
Architect 1	15 August 2014	Working relationship, contacted via email	• Business Director of a medium sized practice, with three offices. • Experienced Architect, and former President of the AIA. • Specialises in domestic and medium sized commercial buildings. • Estimated to be in his late fifties
Building Designer 1	7 August 2014	Direct contact via email after review of past works	• Business Director of a building design office. Which contains in-house mechanical/HVAC engineers. • Experienced Building Designer • Specialises in sustainable building design • Estimated to be in his late forties.
Builder 1	13 August 2014	Working relationship, contacted via email	• Business Director of a domestic sized building contractor • Experience Builder, domestic and light commercial • Specialises in the construction of high-end, architecturally designed, sustainable houses. • Multi-award winning sustainable building contractor • Estimated to be in his mid-thirties
Builder 2	5 September 2014	Direct contact via email	• Business Director of a domestic sized building contractor • Experience Builder and subcontractor. • Specialises in renovations, extension, asbestos removal and new homes. • Estimated to be in his early forties
Client 1	8 September 2014	Progenia Client, contacted via email	• Middle aged - husband, wife and one child • Want to build a home that will suit their changing life into retirement. • Do not plan on moving from this home. • Seek a low impact design, construction and operation.

Client 2	4 September 2014	Progenia Client, contacted via email	• Middle aged family - husband, wife and two children. • Want to build a home that will suit their changing life into retirement. • Do not plan on moving from this home. • Seek a low impact design, construction and operation.
Client 3	4 September 2014	Referred to by others, contracted via email	• Client estimated to be early fifties - husband and wife. Children have moved out. • Want to create a home for them and their business. • Seek a low impact design, construction and operation.
Client 4	11 September 2014	Contacted researcher, contracted via email	• Client estimated in their mid-forties - husband and wife. • Passionate about straw bale house construction, and low impact materials. • Very low budget, construction is heavily reliant on their own efforts.

5.2 Commissioning a Sustainable Home - Interviewee Reponses

This section illustrates how the professional and client interviewees responded to the interview questions. Defining, and how best to deliver 'sustainability' has been a long debated topic, but some researchers believe that the management of their delivery is the key to effectively delivering significant, embodied energy and operational energy results at a marginal increase in capital expenditure (Eid, 2003, Robichaud and Anantatmula, 2010, Zhang and London, 2011). With respect to the key finding found in Chapter 2 and Chapter 3, the interview questions were based on the following areas:

1. Sustainability: How it is defined by each stakeholder group - client, designer and builder).
2. Project Failure: How a project failure (or part-thereof) is defined by each stakeholder group.
3. Project Risk: What is considered a project risk, and how is it identified and managed by each stakeholder group.
4. Project Stakeholders: How each stakeholder defines their interaction and contribution to the design and construction of sustainable homes.

5. Client Objectives: What is defined as a client objective (project objectives), how they are derived, managed and delivered.
6. Decision-making: How project decision are made with respect to the contextual situation and their 'knock-on' effect in delivering client objectives.
7. Project Budget Management: How is the project budget managed against the design evolution (inc. sustainable features).
8. Overall Building Performance/Sustainable Features: How is expected building performance related to sustainable features and construction cost. In addition, how are they validated.

Before these questions can be answered, the professional (design and construction) interviewees were asked what they felt currently hinders the delivery of sustainable houses.

Hindering Sustainability:

Each professional interviewee discussed hindrances that affect the delivery of sustainable residential developments. For this interview question, the interviewer asked this question without any pre-conceived context, meaning the question was asked to the interviewee without giving specific examples (to elicit what they consider to be the most important hindrances for 'sustainability'), however it was asked that the interviewees consider the entire development process - throughout design, approval/governance and construction process. The discussed hindrances from the professional interviewees revolved around three factors, they were:

1. Government regulators

Building guidelines/regulations and government regulators were considered a hindrance to sustainable developments/practices by the interviewed designers. The approval process focuses the government regulators to only evaluate a development proposal against the relevant local government LEP and DCP. The hindrance was expressed in the interpretation and enforcement of the guidelines/regulations, which leads 'good-sustainable-design' principles to the way-side to *interpretative* compliance.

2. Education

Education was considered important by all professional interviewees, but from different perspectives. There was a good general understanding by all professional interviewees regarding sustainability as a general topic, the perspectives differed in the impacts that

education and awareness have in the delivery of sustainable homes. Both designers expressed a similar explanation to this hindrance; however they had a different philosophy and business approach to dealing with it. The consensus between the designers was in the lack of general education about sustainability amongst their clients. The designers also felt that the government, builders, sub-contractors, suppliers, and real-estate agents had a general lack of awareness in current methods and technologies used to design, construction and validate sustainable residential developments. The building designer felt that it was their responsibility to educate their clients in general sustainability, and their professional working relationships in current methods and technologies because they bring together the design concept. The level of general education regarding sustainability awareness within the general domestic market place, and the government regulators were considered the greatest hindrance and an ongoing educational 'battle' during the design process. The interviewed builders considered the education hindrance from a different view point, and felt that the designers needed to pay more attention to the budget and time.

3. Budget and time

Budget and time was a hindrance identified by the interviewed builders. This hindrance is a result of project specific challenges and constraints - where the project manager, or builder in this instance needs to manage "...[firm] time schedules, inadequate or uncertain budgets, designs that are near the feasible limit of achievable performance, and frequently changing requirements" (Zwikael and Ahn, 2011). Builder 1 noted that the budget can create specific and rare opportunities for innovation, but only when the client has the financial capacity, and champions the desire to achieve an extraordinary, sustainable result.

In summary, the interviewed architect and building designer expressed the same hindrances: government regulations, and general education and awareness. Government regulations stipulate guidelines that sustainable innovation must conform, and educating the client in sustainability to make the most appropriate decisions during the design and construction of their house. The builder interviewees were also in agreement, with more consideration to the budget, time and education. Their point of view was from a construction budget and feasibility concern. In addition, for the builders, education was considered as a hindrance, however from a difference perspective. They felt that designers needed to take more control

of the design and verifying construction practices to the project budget, to ensure the designs where 'on-track' to deliver final project objectives.

The above findings align with conclusions made by H. Rasekh (2013). H. Rasekh (2013) outlined that the greatest challenges in delivering sustainable developments lied in the level of awareness in sustainability amongst designers and contractors, and the managing of project budgets with respect to the added project complexity. This therefore concluded that a greater understanding of materials, technologies and verification methods for practitioners is required.

Why Build Sustainably (Client Motives)?:

For each interviewed client, the idea and decision to design and build stemmed from a decision process prior to looking for available land/occupied blocks and designer/project manager. For personal and conditional reasons, this path was an option and inevitably chosen by each of the clients. The path for each client was different, but their needs seemed to align.

In addition, each of the clients had an innate desire to lower their impact on the environment, lower their operational expenses, lower maintenance and create a comfortable and long-lasting home that evolved to their changing lives. Therefore, before each client engaged a designer, they conducted their own research into sustainable design, products, technologies and construction practices. The client interviewees found it difficult to find a designer and builder that could deliver their objectives within set constraints.

To build sustainably, we must first understand what sustainability means. Table 15 outlines what sustainability means for each interviewee.

Table 15: The Meaning of Sustainability - Interviewee Responses.

The Meaning of Sustainability	
Interviewee	**Comments**
Architect 1	Sustainability in residential development relates to *"...the focus on meeting the needs of a client, socially and financially"*. Environmentally specific, the focus is on passive design and material selection. Any other governance stems from government regulations (i.e. BCA and BASIX).

Building Designer 1	*"Sustainability is a word with diminishing value*". The building designer considers sustainability holistically in during the design - accounting for the long term consequences of decisions, including liveability (social) and cost, to reduce total project impact on the environment. Additional comments from the interviewee: *"Generally, consumers only associate technical terms like energy efficiency and water tanks to sustainability and not the wider context. Where builders only pay 'lip-service' to the notion, as it has a connotation to disrupting their 'normality', which creates a perceived difficulty and added risk. Typically, tangible and foreseeable low risk options are only proposed by builders, i.e. waste management, site environmental management and tree protection".*
Builder 1	*"A sustainable home is one that best encapsulates its location, the client needs, and [project] constraints into the overall design and construction [outcome]".* Sustainability within a home begins with ensuring a good passive solar design and a good thermal envelop. In addition, sustainable houses must use materials that are renewable and sustainably sourced (e.g. FSC timbers). Site waste and environmental management is also a critical factor that is generally overlooked during the design. Minimising waste and controlling environmental effects can also reduce construction costs.
Builder 2	*"Sustainability within housing is a 'work in progress', which typically is controlled/governed by build cost."* Build cost inevitably dictates the overall result of a project, however good management of build costs and greater knowledge on materials, waste management and construction methods facilitate the construction of more sustainable home.
Client 1	Sustainable housing is more than just 'taking-care' of environmental considerations - it is only one factor. A sustainable homes shall embody the needs of the client (build cost, spaces, functions, maintenance, and running costs), their evolving lifestyle.
Client 2	A sustainable home starts with the liveability and 'future proof' of the house. It must function, perform and cater for a changing life-style and makeup of the family. Secondly, it needs to have the 'basics' covered - for this client, this refers to a building that that takes advantage of orientation, prevailing winds and the sun (passive design). Thirdly, the building must operate as efficiently as possible and built from environmentally friendly materials (renewable and recyclable).
Client 3	The three core aspects for sustainability are: thermal comfort (internal air quality, natural ventilation, passive design and heating & cooling), material selection (recyclable, renewable resources, performance, maintenance and locally sourced - as much as possible), and 'Future Proofing' (the form and function of the house can adapt to their changing life styles).

Client 4	The core concept of sustainability for this client is material conservation, local material sourcing, renewable materials, and materials that are not harmful to the environment and human health. Secondly, the home must be efficient to own and operate.

There interview responses regarding sustainability awareness were generally in consensus, to design and construct a house that is tailored to the clients' specific needs, while maintaining the product budget and reducing environmental impacts (energy, water and embodied energy).

5.2.1 A project failure, who is to blame?

A project failure can be considered in many different ways, and is generally instilled by the contractual nature that brings stakeholders together to deliver a project (Pinto and Mantel Jr, 1990, Belassi and Tukel, 1996, Kent and Becerik-Gerber, 2010) - developing a matter of perspective. As noted in the previous chapter, aligning project objectives with stakeholder incentives is critical to the delivery of a successful project. This leaves the question, how do the key stakeholders, in the delivery of residential developments define a project failure, and how is this related to the connectivity of their relationships?

Table 16 outlines how architects, building designers, and builders define what a project failure means to them.

Table 16: What is a Project Failure?

Project Failures	
Interviewee	**Comments**
Architect 1	A project failure is an unsatisfied client, with respect to two factors: the clients social requirements and the project budget. At the end of a project, the overall success of a project is determined by external parties conducting interview and questionnaires with clients - this only covers aspects of their initial brief with the Architect, i.e. only social and financial factors. In addition, partial project failures are not specifically considered, only the overall satisfaction of the commissioning client with their work.

Building Designer 1	A total project failure was expressed as a project that does not take place, i.e. The design is never constructed (this is typically due to budgetary issues, which stems from not understanding the budget at the initial design brief and considering this hard-constraint during the design concept and detailed design stages.). Partial failures are the most common failures within projects, and generally involve shortfalls in expected building performances. This is generally a resultant from design changes and building errors from the initial design (design intent), which propagate from a client-builder relationship (i.e. the designer is not engaged in the quality assurance during the construction)
Builder 1	A total project failure is determined by the clients 'happiness' at the project's completion (building handover). Internally, a successful project must be gauged by the financial profitability of each business and professional (stakeholder) involved in the project. It is expected that each person or entity involved should make a "fair and reasonable profit". The interviewed builder felt a responsibility to this aspect of the projects success, which is felt to be best achieve through clear communication and contracts between all associated stakeholders (e.g. subcontractors, suppliers, consultants, and the client). For sustainable residential developments, sustainable design intent is always at risk of project failure, due to stakeholder education and budgetary constraints.
Builder 2	A total project failure is when the builder and/or the client is not happy with the overall result at the end of the project (based on personal perceptions). To achieve an overall success for a project, the interviewee expressed the importance of clear communication and documentation between the client, the designer and the builder. Examples of potential minor failures were presented, but not discussed by the interviewee.

From the above tabulated results, conclusions can be drawn base on the different responses. Each interviewed professional outlined, with reason, what they constitute as a project failure, they have been summarised holistically into four items:

- Client satisfaction (from varying view points),
- Project 'completion' (dependant on the scope of work of the interviewee),
- Achieving project outcomes (perceived value), and
- Stakeholder profitability (project implementation - construction only).

The above items relate to Pinto and Mantel Jr (1990) three project evaluation categories (implementation process, perceived value of the project, and client satisfaction), which cover both internal and external project evaluation for overall and partial success and failure. What is more important, is which of the above items are considered, and how much emphasis is placed on each item by the interviewed key stakeholders. Architect 1 focused on ensuring

that their design service, as a service, is monitored and evaluated because it was felt that managing and implementing a high-quality design service will led to positive design outcomes. Building Designer 1 considered that a none-construction design is the greatest failure, because it reflects directly between the suitability of the design and the needs and constraints of the client. Secondly, Building Designer 1 describes the miss-implementation (by deliberate change of design, or its incorrect construction) of the design indent as a key failure. Builder 1 and 2 focused on the clients satisfaction as most important. Typically, this meant delivering the design to (as close as possible) the clients budget, and therefore the design/construction decisions were made with a higher emphasis on cost - i.e. the cheaper the build the happier the client.

<u>Client Surprises, a indicator of project failures:</u>

This section of the research is critical in matching identified project failures (by the interviewed professionals) to the management of project risks, from the perspective of the commissioning clients. At the summary of all interviews with clients, there were three key project failures identified: budget management (overruns), number of design iterations/changes (knock-on effect from budget overruns), and design-contractor rebellion for proposed 'sustainable features'.

For every interviewed client, they expressed that budget overruns were the greatest surprise (failure) during their project. For Clients 1, 3 and 4, it was noted that the control of the budget was lacking during the delivering of the design, and only noticed when the project was being tendered to builders for construction. Typically, client project contingencies were not expressed to the design or construction professionals, only the need to reduce cost. In the case of the interviewed clients, they responded as follows:

- Client 1: Reduce the cost of Prime Cost (PC) Items, and increase their overall budget amount. The form, shape, finishes and 'sustainable features' were able to remain.
- Client 3: Change to the initial (DA approved) design, to reduce the overall scale of the project (floor area reduced by approximately 13%), the initially specified slab on ground has been removed, and items of the build contract have been left out and will be completed by the client when possible. All notable 'sustainable features' remained.

- Client 4: Client 4 was unable to continue their project into construction, with the documented design intent and construction method (building contractor). The design is currently being changed and the home-owner builder option is being considered.

Client 2 also experienced an overrun in their original budget, but this was the result of trying to achieve all of their social requirements within tight constraints - financially and site conditions. The client explained that this resulted in a lot of design iterations, which also re-defined their needs, to find a solution that would meet their financial constraints. This case is notably different to the previous three (3) client cases, where the validation of the cost was only realised at tendering stage, and not during the design. In addition, Client 2's project was managed by a project manager, while Client 3 and 4 were championed by the clients.

The third surprise, which was identified by Client 3 and 4, was contractor resistance to the sustainable design intent. The contractors questioned the 'need' of their inclusion, and in both cases referred to *common practice* materials, details and solutions. The three noted objections were the use of double glazing (as opposed to an 'e-coating', single float), the need for the inclusion of phase change material, and the use of straw bales instead of standard construction. Client 1 and 2 were managed by their project manager, i.e. the researcher. For the two case study projects, the researcher also experienced reluctance by contractors. The researcher notes that the reluctance typically came from three ideologies, they are:

1. All tendering contractors felt that their tendering pricings would not be comparable to others, as they are not as confident in pricing foreign products/materials/systems.
2. A perceived risk of using untested (by them, or common builder practices) products/materials/systems.
3. The need for the specified sustainability features. Each contractor tried to 'sub-in' traditional building practices, e.g. single glazed low-e for double glazed and the need for insulated plasterboard and high R-value rock wool batt (stating the high R-value rock wool batt is sufficient).

The three noted surprises by clients needs to be considered by each of the key stakeholders, and each stakeholder engaged should consider these surprises as failures - and therefore put

measures in place to mitigate their severity and occurrence. In addition, a connection can be made between the professional stakeholders identified failures, the surprises listed by clients and project risks. All professionals listed 'Client Satisfaction' as the most important risk and therefore failure to avoid - but from the interviews, little seems little effort in placed in managing the clients 'surprises'.

5.2.2 Project risks, defined by perspective

Like a project failure, project risks can be considered in many different ways - each varying by the perspective of the stakeholder. A project failure is the result of a project risk that was not effectively mitigated. During the interviews with the professional interviewees, two categories of risks were identified: project risks and delivery risks. A project risk has been defined as a risk to the outcomes of the project, i.e. a risk to achieving the objectives of the project. Whereas a delivery risk has been defined as a risk associated to the company contracted to deliver aspects of the projects scope, i.e. a risk to the sustainability of the company. From the interviews, the following risks were specifically noted with importance:

- Project Risk
  - Development approval risk: The project is not approved for construction and occupation.
  - Project budget: Managing the total project budget.
  - Delivery of project objectives: Achieving the objective of the project.
- Delivery Risk
  - Requirements capture: Inaccurate requirements capturing from the client can result in an unfavourable result.
  - Market Value: Managing client expectations with respect to the built result with respect to the project budget.
  - Project budget: This is with reference to each company, not accurately addressing the requirements of the project with adequate resourcing.

The professional interviewees were in consensus regarding the above stated risks. However the risk profile for a specific risk changed dependant on the relation of the stakeholder (i.e. interviewed professional). For example, the construction professionals noted that the risk to managing the construction budget (the market value of their service, and success of their

business) amplified by the typical advice and design given by the design professionals, i.e. the project design and budgets are typically not reflective of construction budgets. A similar conflict in risk profile occurred between the delivery of project objectives. The interviewed designers aimed at achieving each project objectives listed in the client brief, with a specific focus placed on the objectives that align with their area of expertise. This is similar to the construction interviewees, except their area of expertise is in construction budget management. This void instigates conflict between the design intent and the project construction budget. Therefore builders, in consultation with the client and/or designer, reduce design intent to achieve the projects financial objectives. To mitigate this risk, the designer must, more carefully evaluate the projects budget with the concept and detailed design to ensure a more optimised balancing of project objectives.

Table 17: What is a Project Risk?

Project Risks	
Interviewee	**Comments**
Architect 1	The Interviewee identified four main project risks, they are: 1. Managing of project cost, 2. Accurately capturing client requirements (to create the brief), 3. Meeting client expectations (achieving the brief) and 4. Delivering the project (construction). The following outlines how Architect 1 manages these risks: Project cost is controlled by engaging suitable professionals (e.g. quantity surveyors), domestic builders are also engaged during the concept stage, although it is noted that they generally are less effective at predicting final construction cost at the design concept stage. The quantity surveyor bridges the gap during design concept and detailed design, when the domestic builders quote for the project. Capturing client requirements and desires is managed by an initial meeting and a comprehensive open and closed checklist/questionnaire. At this stage, only social function and form and financial requirements are gathered. To consider more environmental design objectives (other than BASIX), an external expert is consulted and additional costs are outlined. Meeting expectations outlined in the client brief are achieve in a similar manner as controlling client variations. All design decisions and proposed variations are referred back to the design brief. It was emphasised the importance of relating each design decision, and direction for the project back to the past decision and to the design brief. Allowing the design to evolve (to build on information/decision), and not merely 'change' without direction. Delivering the project, construction risk is managed by an internal process. It entails a tender process - with uniform pro-formas, and detailed documentation. Provisional sums are considered and unit rates confirmed.

<table>
<tr><td>Building Designer 1</td><td>"The greatest project risk is not achieving the initial project objectives and sustainable outcomes, that are outlined in the client brief. This risk primarily stems from prioritising other perceived gains over sustainable outcomes. e.g. from budget constraints, sacrifice grey water treatment and retain the granite bench top."

In addition, the level of education regarding sustainable housing is a risk, in relation to the client and their extended relations (family and friends). This risk is based on the influence of non-expert advisers have on client decisions (generally builders).

The project risks are best managed through education (client and professional associates) and communication. Continual client engagement and involvement, coupled with a 'stepping-stone' program of sustainable housing education helps mitigate this risk, by keeping the client continually updated with design, decisions made, their holistic implications, and the value of each decision to achieving overall project objectives. The educational approach by the building designer must take into account the clients level of knowledge, and use this as a base starting point.

This failure, or project risk, is managed by more detailed documentation, which shifts accountability to the builder and client. The most effective solution is having more control, and being involved in the delivery of the project, so compliance can be more effectively managed. It still happens but you have the documentation. It might be the clients failure (risk mitigation).

Planning stage is an unavoidable risk, either Development Application or Complying Development. It is felt that most planning documents are written with good intent, but the risk is apparent in the administering and governing the planning documents. Personal agendas by the administering town planner can come into play, which are unavoidable for any project DA submission. In addition, within the NSW housing code, 'blunt objects' hinder 'general rule' sustainability, i.e. solar access, orientation and passive design. "For example, the planning process relies on BASIX to measure a houses level of form and sustainability merits. Due to its innate nature, will never bring a sustainable solution to the building industry."</td></tr>
<tr><td>Builder 1</td><td>The core risk for a project is the control of the construction budget. There are two key areas of budgetary risk, they are described as expectational risk (i.e. the client expects more from their money) and design changes, which effect the overall construction costs (either from the client or designer/architect).

These project risks are controlled by this builder through clear communication, through ongoing face-to-face meetings. The communication shall entail accurate meeting minutes, and monitoring of construction progress (i.e. time, budget, procurement and quality). Typically, the budget is managed by 'dropping' off initial design requirements/intent. For example, sustainability features get reduced/changed to 'make-way' for the variations and/or additions.

Sustainable outcomes (design intent) is always at risk due to budgetary constraints, not achieving pre-set objectives is also a failure. It was expressed that the best was to manage this risk was by clear documentation and explanation to the client, and clearly expressing the benefits and knock-on effects of changes/reductions in sustainable features.</td></tr>
<tr><td>Builder 2</td><td>A total project failure is when they and/or the client is not happy at the end of the project. Note, there was no formal measure or survey mentioned to gauge overall satisfaction at the end of a project - only based on personal perceptions. Referring back to original intent is not considered.

To achieve an overall success for a project, the interviewee expressed the importance of clear communication and documentation between the client, the designer and the builder. Examples of potential minor failures were presented, but not discussed by the interviewee.</td></tr>
</table>

5.2.3 Stakeholder Management to Effectively Delivery Sustainable Residential Developments

The understanding of stakeholder interactions and influences, and aligning their objectives with that of the project is critical in delivering a successful project (Yang et al., 2009, Yang and Shen, 2014, Newcombe, 2003, PMI, 2008). Stakeholder management is best addressed through mapping their relation to the project and monitoring and managing their objectives, perceptions and influences over the life of the project (Newcombe, 2003, Yang et al., 2009).

Industry professionals in residential design and construction were asked how stakeholder management is applied in practice - from their point of view. The building designer and architect considered there to be three key stakeholders, they are: Client (building commissioner), Designer/Architect and the Builder. They also considered the structure of the stakeholders were inherent to the contractual nature of the project - i.e. if the project was self-managed (i.e. by the client), or the designer, or the builder. In any case, Architect 1 expressed the importance of a clear and communicated brief, to ensure each stakeholder agreed upon, and had ownership in delivering the projects objectives.

The two builder interviewees expressed similar concerns with the current business practice/structure in delivering residential developments. The identified concerns that hindered a more successful delivery of project outcomes are:

1. Project Champion (i.e. specified project manager)

Typically, project managers are selected (the client, designer or builder). However, there was no evidence that a connection was made between the 'project manager' designation and the flow on influence of their responsibilities to stakeholder management through contracts, risk profiling, documentation, mapping and evaluating. A more 'ad-hoc' approach to the project manager's responsibilities was evident, allowing for a 'scatter' of stakeholder objectives and therefore a hindered project outcome.

2. Ineffective stakeholder mapping:

The lack of consideration for subcontractors, suppliers, employees, local government and the general public. The builders presented the specific importance of the relationships and contractual importance towards subcontractors, suppliers and their employees. Managing these relationships is critical to the success of the project and the building company. They

have specific influence of the construction cost, building quality, project duration and the projects various social responsibilities (e.g. safety).

3. Undefined stakeholder boundaries (relationships, roles and responsibilities)

Stakeholder boundaries relate to the relationships, roles and responsibilities of each engaged stakeholder to the project. Undefined boundaries represent 'grey' areas of responsibly between the project stakeholders. Typically, this is a result of unclear and/or unspecified requirements in contract documentation. The builder interviewees consider the supplied drawings and specifications as the most important contractual documentation. The building documentation needs to reflect the objectives of the project, and therefore align with the objectives of each stakeholder. For Builder 2, a greater level of risk is associated with 'low' standard drawings. In addition, each interviewee expressed varying levels of overall project risk associated with low standard drawings. However, it was evident that there is a different level of expectations between the designers and builders as to what is deemed 'suitable' in terms of document (drawings and specifications) 'quality'. The interviewed builders stated that design documentation needed to be increased, whereas the designers stated that their documentation is higher than required.

The most evident divergence between the current stakeholder relationships, and achieving a desired project outcomes stems from the contractual nature of their connection. Not enough emphasis is placed in ensuring the project objectives are reflected accurately in the projects contractual documents, and effectively validated, which allows a separation in stakeholder objectives. The designer is trying to reduce internal costs by asserting 'minimal' work internally (towards a project drawings and specifications), while still trying to achieve the client brief. The builder is attempting to mitigate risk by increasing the cost of the project (due to 'minimal' information), and reducing the overall project scope to maintain a remembrance to the original project budget. In all illustrated 'best case' stakeholder diagrams (illustrated in APPENDIX G: Interviewers Reports), they were interweaved with stakeholder actions/deliverables. The stakeholder map needs to delineate the hierarchy of responsibility and stakeholder appointment.

Table 18: Stakeholder Interviews with Design and Construction Professionals.

Stakeholder Interaction	
Interviewee	**Comments**
Architect 1	Two flowcharts (refer to APPENDIX G: Interviewers Reports, page 231) were scripted to describe stakeholder management over the design and construction process, a 'typical case' and a 'best case' flowchart - which is suggested to be an optimised solution. It was expressed that the typical case evolved through the conditioned nature of business, legislation, litigation and compliance protocols (development approval processes) - but in most instances, hinders the delivery of more successful houses. For both instances, the aim is to enhance communication between the stakeholders. It was expressed that this could be more effective in the proposed 'Best Case' flowchart. The client, architect/building designer and builder should be involved at the commencement/commissioning of the project. This would allow for a more accepted and holistic client brief, and each key stakeholder has a complete understanding, input, ownership and can add their knowledge and experience to ensure an achievable client brief.
Building Designer 1	Stakeholder management was not specifically discussed, the discussion focus shifted more heavily towards managing sustainable objectives with client requirements. However, connections can be drawn between the interaction of the key stakeholders. The designer expressed the importance of a high level engagement with the commissioning stakeholder (the client), and keeping up to date with the legislative requirements to better control the development application process. Building/Designer stakeholder interaction depended greatly on the type of contractual requirements set out by the building commissioner.
Builder 1	Stakeholder management was comprehensively discussed, and how the interplay between each stakeholder occurred with difference contractual circumstances. The interviewee draw a flowchart (refer to APPENDIX G: Interviewers Reports, page 231) that outlined the relationships and responsibilities between the 4 stakeholders: the client, architect/designer, builder and subcontractors/suppliers. A diagram was drawn to explain the relationship between the stakeholders, and their typical specific overall goals. The diagram illustrates that the builder wears two hats, one in design and the other with delivering the design. Depending on the contract, any of the 'design' team can be ultimately take responsibility for the overall delivery of the project. It was noted that this method can cause conflict between the builder, and the other stakeholders because boundaries are not clearly defined and managed.

Builder 2	The key stakeholder interactions was comprehensively discussed, and interpreted in the form of a flowchart (both typical and preferable) - refer to APPENDIX G: Interviewers Reports page 231). The interviewee believed that the current flowchart (industry environment), from the point of view of the builder has two inherent flaws with respect to delivering an overall successful projects. Firstly, to successfully deliver a design that connects the clients essentials and desirables, project constraints (hard and soft), and the design team to the construction team (inc. construction budget). In addition, the disconnect between design, construction and construction budget is also typically experienced during construction - and championed by the architect/designer, generally placing their own 'agenda' in front of needs and constraints of the client. Secondly, the tendering and construction of the project with the construction team (i.e. the builder, suppliers and subcontractors). "*The current process requires accurate documentation and tendering procedures to ensure subcontractors quote accurately, and each tender price are comparable - 'apples with applies'.*" In domestic practice, it is expressed by the interviewee that the accuracy of documentation and the 'ad-hoc' nature of the tendering process instils a level of assumptions, allowances, inaccuracy in pricing, and therefore a incompatibility of tender prices. The proposed and preferred stakeholder structure places more responsibility on the architect/designer to validate their design decisions, material selections and even consider the construction methodology during the concept design. It was suggested that this could be done via a Quantity Surveyor, and/or liaising with suppliers, subcontractors and builders during the design stage. In addition, construction budget validation should allow architects/designers to invest more time (with confidence) in detailed documentation, for more complete documentation. The second amendment to current practice stems from the more complete documentation. For typical building projects, this will allow the building contractor to be more engaged with the client, and work with them one-on-one to deliver the accurately documented house. With the original architect/designer only involved when necessary - and not championing this stage of the project.

5.2.4 Project objectives, the development of the client brief.

The project objectives are outlined at the commissioning stage of the project, which in-turn, paves the way to developing the project plan (PMI, 2008) and the stakeholder structure (Yang et al., 2009, Akadiri, 2011). However, Akintoye and MacLeod (1997) outline that the project plan and stakeholder structure bare their own innate implementation risks that need consideration in their development. In the design and construction industry, the project objectives is named either a 'Design Brief', or 'Client Brief' (Nervegna, 2006) - in this thesis, this document will be referred to as the 'Client Brief'. Nervegna (2006) outlines the importance of developing a comprehensive client brief, that contains the critical needs and requirements of the client. In addition, Nervegna (2006) suggests the following design brief considerations be adopted to generate a grounded foundation from which a sustainable development can prosper:

1. <u>Site Planning:</u> While the streetscape and views are important, the building's design should respond to the site's environmental opportunities - namely through passive design opportunities. In addition, the site could have an influence on the material

selection because of location, difficulty (construction type), and durability in different geological areas.

2. Built Form: The building shall comply with governing regulations, such as building setbacks, easements and streetscape bulk. However, while considering a design that conforms to regulations, this can have an impact on the energy efficiency of the design.
3. Internal Layout: The internal layout must reflect the needs of the client, in terms of spaces (rooms), function and form. While considering the layout form, the zoning of spaces is also important in terms of heating and cooling demands and sound separation.
4. Materials: construction materials is a critical aspect of a buildings overall aesthetics, form, function, construction methodology, energy performance, maintenance and ecological impact. During the material selection, the following should be considered: materials cost, installation cost, construction details, material performance (durability and thermal properties), warranties and maintenance, and embodied energy.
5. Insulation: Specify correct insulation to floors, walls, roof and windows and door openings. Basic requirements are stated within the Building Code of Australia (BCA), but they are easily exceeded. Insulation levels shall be matched with thermal comfort, energy analysis and initial construction costs.
6. Energy: The following shall be considered in the building form and layout design; use of renewable energies, passive solar design (i.e. building form with building fabric properties), natural ventilation, natural day-lighting, and low energy fittings and appliances.
7. Finishes: Ensure a high level of internal air quality, avoid the use of products with high levels VOC and formaldehyde. It is important to ensure the products selected match the level of finish and warranties of the client.
8. Waste & Recycling: Waste reduction during construction through material selection and detailing and construction management processes. In addition, the selection of recycled of materials, and materials that are recyclable.
9. Water Use & Reuse: The onsite use of rainwater, recycled water and water efficient products to reduce the demand of water from the mains (town water).
10. Development Life Cycle: The design, construction and operation of the building should be considered over the buildings life time, and evaluated against the cost and

ecological impacts. In doing this evaluation, the following shall be considered; embodied energy, construction cost, running cost, maintenance requirements, pollution minimisation and the potential for re-use and/or change of use (adaptive design).

Nervegna (2006) research provided a founded basis to develop a client brief that considers the client's needs with environmental considerations. However, the research did not contain any mention of project budget, and financial management with respect to the 10 suggested considerations.

During the interview process, the client interviews were asked to describe how their needs and desires were gathered and incorporated into the project. In addition, the professional interviewees were asked what information they capture, and how this information was captured and embodied into the overall projects objectives.

Commissioning Your Home - How a client's needs and desires were captured

All client interviewees expressed their desire to design and build their own home, but required a particular personal and conditional set of circumstances. In all four interviews, the clients were seeking the security of a design professional that could deliver on their needs, while also mitigating the potential risk of project cost overrun. In addition, deciding on a design professional that also incorporated the use of passive design, and active systems to create real reductions in overall running cost with improved internal thermal comfort.

There were three common trends identified amongst the client interview responses.

- Difficulty in finding and engaging a design consultant that was able to define and deliver a more sustainable and energy/water efficient home;
- A need to be proactively involved in the over the design process; and
- Developing a sense of rapport with the consulting professional.

Clients 1 and 2 engaged the author of this thesis to design and project manage their houses. The capturing of these two client requirements was conducted prior to the publishing on this work, and therefore 'action research' was utilised in developing this aspect of the thesis deliverable - the sustainable residential development project management framework. The

method to collect the requirements for Client 1 and 2 was a hybrid approach between the client's needs (a brief description can be found in Chapter 7) (in terms of form, function, aesthetics, cost and maintenance), which were captured via web-based building scrapbooks Pinterest (2015) and Houzz Inc (2015), and a questionnaire that comprised of quantitative and qualitative, and closed and open questions that asked questions based on total budget, room types, number of rooms and function of rooms. In addition, the second aspect of developing the client brief relied on decision-making around achieving the highest levels of thermal comfort, energy efficient and overall life-cycle analysis in terms of building form and the specified budget.

Client 3 was exposed to the most comprehensive building design briefing, which entailed four key aspects, they are:

1. Overall project goals (inc. financial)
2. Liveability goals (how and where they currently live - including flora and fauna, and how this home will compliment and add to the changing lives)
3. Sustainable goals (materials, water efficiencies, electrical efficiencies - typically qualified, quantifying goals and validation could have been requested)
4. Site and local government constraints.

However, Client 3 felt that the design briefing process cannot be standardised, and must adapt to each new situation - i.e. client, desires, location and engaged professionals. The process needs to remain fluid, to ensure an accurate capture of the clients requirements, but still obtaining defined objectives.

Overall, the clients felt the most important aspect of the design process is trust, instilling trust in the designers ability to deliver what they want/expect - especially with the environmental features.

Table 19: Deriving the Client Brief - Capturing and Delivering Client Objectives

Capturing & Delivering Client Objectives	
Interviewee	**Comments**
Architect 1	A high emphasis is placed on the client brief, it was expressed that the client brief is the most important document to guide the project. Determining the objectives/content of the client brief is completed via a proforma which details the social and financial requirements of the client. This proforma is then discussed at the initial meetings to 'flesh' out exacting requirements. The client brief is then agreed upon by the client and architect.
Building Designer 1	Capturing the requirements of the client and their objectives. The commissioning of a house by a client starts with the design brief, this brief must capture objectives at high level. For example, it must contain person requirements for the buildings usable space, but also the projects constraints (e.g. land conditions and limitation, DCP conditions and client budget), and design performance criteria (e.g. energy performance, recycling and water reuse). "*To accurately capture and define the client brief, clients are encouraged to do some preliminary reading, for example 'Your Home Technical Manual' (especially the sections on passive design and the introduction chapters on energy and water). This begins the 'education process' for the client, and eventually helps them understand exactly why and how their house was design and constructed in its final form. It also gives them an inner understanding of how the building functions.*"
Builder 1	From the builders perspective, they are not involved in the development of the clients brief, this is typically prepared and given by others. Which can create conflict when trying to deliver unrealistic objectives with defined budgetary constraints. It was expressed that in recent times, clients approach the builder (the interviewee) for advice and guidance during the design process, which is felt to better balance design with expected project outcomes by providing more 'realistic' construction parameters (construction parameters area site conditions, site access, site logistics, construction process, materials, construction time and construction budget). Generally, there is conflict between the initial client brief (i.e. outlined constraints), and delivering a house as per the initial design intent. The design needs to be further adapted to suit the construction parameters.
Builder 2	Typically, the builder is not involved in the project when the project objectives are derived. The interviewee explains that this can create conflict, especially when the clients 'hard constraints' were not adequately considered during the design process. Generally, this refers to a miss-match in designer construction budget estimates and builder quotations, but this can also refer to constructability of the building concept. The interviewee explains that they are typically engaged during the house is waiting for or has DA approvals. At this time, the interviewee has no 'formal' method of capturing client objectives, but merely response to the documented design and the clients budgetary constraints.
Client 1	The requirements and objective for this Client was initially conducted via a 'dumping of ideas' from online 'scrapbooking' websites - i.e. Houzz & Pinterest. In addition, a pro-forma was used to collect social, financial and environmental essentials and desires. In this case, the client felt a lack of connection between the decisions being made, the initial data collection and their involvement.

Client 2	The process started with engaging the researcher, who specialised in sustainable building design. The requirements for the project were collected with the means of a client brief 'pro-forma' (form, spaces, budget, uses), and the use of 'Houzz' [houzz.com.au]. Relating the interconnectedness of the initial requirements was difficult - social requirements, expected build cost, thermal performance, energy efficiency, water treatment, materials/finishes, local government requirements and site conditions. In reflection, marrying the initial requirements during the design process gave clarity to what is important in the design, and define and refine how the spaces will be used. An observation by the client, in addition to the listed questions. They felt that a more effective method to understand the clients experience, knowledge and background would help the professional 'ask the right questions'. This would more effectively 'flesh-out' the initial requirements. In addition, during the requirements collection stage, the engaged professional should 'paint' a greater picture of what is to be expected during the entire process, throughout design, compliance and approvals and construction.
Client 3	The process started with engaging a 'Building Designer', who specialised in sustainable building design. The Designer collected four core project objectives, they are: 1. Overall project goals (inc. financial) 2. Liveability goals (how and where they currently live - including flora and fauna, and how this home will compliment and add to the changing lives) 3. Sustainable goals (materials, water efficiencies, electrical efficiencies - typically qualified, quantifying goals and validation could have been requested) 4. Site and local government constraints. In hindsight, the client feels that this process cannot be 'typical', because of the rigid nature of the industry. It currently requires 'champions' to push the 'envelope' and drive the delivery of a 'sustainable' home - one home at a time.
Client 4	The building designer was specified because of their previously experience with straw bale house design. The Client have the designer 'free reign' to develop the concept, trusting their artistic direction for the project. No specific method/s were identifiable to the Client for the collection of personal requirements and constraints. This seemingly missing aspect of the process did not produce a final design deliverable that suited their needs or constraints.

The professional responses from both the design and construction professionals represent their personal experience in capturing client needs, requirements and objectives. The two design professionals consider the need for the client brief to contain the project's hard constraints - this entails: land conditions, LEP and DCP requirements, and project budgets. Secondly, both design professionals express the importance of accurately capturing the clients essentials and desires. Architect 1 uses meetings and a proforma to derive the client brief, it is explained that a proforma helps guide and 'flesh-out' the clients desires and essentials in the proceeding design brief meeting. The greatest difference between Architect 1 and Building Designer 1's deriving the design brief is not in the method, but in the information captured. Architect 1 only considered the social and financial aspect of the

design - and states that environmental aspects can be considered, but generally at an 'add-on' expense that is calculated by consulting sustainability consultants. Whereas Building Designer 1 has sustainability built in to their core service. Therefore, Building Designer 1 captures information regarding energy performance, water use, materials and thermal comfort.

Builder 1 and 2 both expressed that they are generally not included in the development of the client brief, and generally consulted and engaged at a later stage in the projects life-time (after development consent is issued). However, both interviewees expressed their direct involvement in ensuring the construction budget reflects the project budget outlined in the client brief. It was expressed that in most cases, the design changes in response to financial constraints - with the first amendments being the scaling back of sustainable features.

5.2.5 Decision-making, How Project Decisions are Decided

Environmental decisions for sustainable developments are often complex, multifaceted and connected socially and financially. In most cases, such decisions are intuitively simplified to make the options, and therefore decision, more manageable. During this intuitively ad-hoc process, connectivity to social and financial aspects may be ignored, and 'information may be lost, opposing views may be discarded, and elements of uncertainty may be ignored.' (Kiker et al., 2005).

A large number of decision-making support systems, regarding environmental and energy consumption aspects, for building developments have been based on the Life Cycle Assessment (LCA) (Juan et al., 2010). This can be attributed to the general acceptance of LCA within the environmental research community as a valid method to compare decision options with respect to materials, components and services (Cole, 1998). However, (Cole, 1998) outlines that the widespread adoption of the LCA approach will be limited because of its complex nature "…in [which] it involves the aggregate effects of a host of life-cycles of their constituent materials, components, assembles and systems.

The design stage during a sustainable development represents the key moment when influential decisions affecting the three themes of sustainability are made. There is now a

considerable amount of design-relevant information relating to a various environmental issues, far more than that currently incorporated into sustainable rating tools (Cole, 1998).

To bring context to the research literature, the professional and client interviewees were asked how project decisions were made, and from their relation to the project - outlining the level of involvement in the decisions making process. Table 20 outlines the responses to decision making process for all interviewees.

Table 20: Project Decision-Making - Interviewee Responses.

Decision-making	
Interviewee	**Comments**
Architect 1	The decision-making protocol during the design and construction process is ad hoc, and depended on the client. The approach is 'tailored' to the client, to suit the natural temperament of a working relationship. The level of decision-making input is also gauged by this relationship, and managed accordingly.
Building Designer 1	The interviewee did not express the utilisation of a decision-making protocol or process. They expressed that decisions are critical in the overall direction of the project, and to keep the project on-track was managed by education and clear communication with the client. The education level, and adequate information needs to be supplied to the client to allow informed client decisions. Note. No indication was given that projects decision were segregated between the levels of client involvement and decisions made in-house.
Builder 1	The interviewee did not express the utilisation of a decision-making protocol or process. However, the interviewee did express a high level of communication was involved in their business practices. This was reinforced by the interviewee, because it allows them to clearly inform the client/designer to make informed decisions on design and budget related issues. All construction related decisions are keep in-house.
Builder 2	Throughout the interviewees management practice, they ensure the client is involved in every decision, at every level to make sure the client had ownership of their the project decisions - especially with the budget, and knock-on changes to the design.
Client 1	The Client expressed that a greater connection between the outlined social, financial and environmental essentials and desires and the decision-making process during the concept and details design are important. To make this more effective, the client suggested more validity/accuracy is required with respect to the information to allow them to make more informed decisions, with the designer/architect.
Client 2	For the client, it was very important to a part of the decision-making process. The client already had past knowledge in sustainability, and therefore wanted to be involved in the design process. How each decision plays on other decisions, not just in initial form/construction, but overall life-cycle of the building and its operation.

Client 3	For the client, it was very important to a part of the decision-making process. To understand and link their prior learning to the design and decision-making process. This endeavour was a life-changing undertaking, so commanding this was very important, especially with the 'knock-on' effects of the decisions. How each decision plays on other decisions, not just in initial form/construction, but overall life-cycle of the building and its operation.
Client 4	The Client expresses that a more hands-on approach is required to ensure the design evolves to a workable outcome. This requires a more comprehensive capturing of their requirements, vision and constrains. In addition, an effective way of guiding the design towards the most desirable outcome.

From the four professional interviews, it is evident that there is no defined decision-making protocol used to sure the deliberation of informed decisions, internally and with their clients. The discussions were based on a ad-hoc approach to the decision-making process, which included their internal decision-making, their level of client involvement (which was gauged by their client's temperament, i.e. changed based on the rapport between the professional and their client), and the available information (at the time) to make decisions. The two building professionals both outlined an undefined, yet consistent approach to managing decision-making. All decisions related to the construction of the projects seemed to be made internally, either by the builder and/or suppliers and subcontractors. The two main decisions, which they delegated to the client/designer were related to the design, and the associated 'knock-on' financial effects.

The interviewed clients were all consistent in their responses, the three noted consistencies were:

1. Requested a high level of client involvement in decision-making,
2. Requested a high level of detailed information to assist in decision-making, and
3. Requested an understanding of the interconnection/knock-on effect of their decisions.

Incorporating these three needs with a balanced level of education into a decision-making protocol would be an invaluable aspect to delivering a house that has effectively balanced decisions against the client brief - sustainable project objectives.

5.2.6 Project Budget Vs Project Cost

The building design professionals were in alignment in their considerations towards financial management; they both recommended ‘lump sum’ and 'fixed price' construction contracts. A

lump sum or fixed price contract represents the construction conditions and construction quote that is issued from a tendering builder. Both consultants agree with this construction approach because it mitigates cost overruns from unexpected site conditions or design elements that were not accounted for in the agreed upon price. Architect 1 does not mention how they manage the development of the concept design, with respect to the project budget. But it was mentioned that a construction budget check is, at request of the client, completed via the engagement of a cost planner. Architect 1 also outlined that a project does not contain cost overruns during the construction of a project, they are considered as 'extras', agreed upon by the client. At the domestic level, the marriage between the project budget, the design stages and validation (once, by an external party) could result in friction between stakeholders, when expectations do not meet construction quotations - especially in validating the incorporation of sustainable features - historically a more complex design and construction project (De Brucker et al., 2013). Building Designer 1 applies a different approach, and outlines that their design approach (concept development) adapts with respect to the outlined project budget. This is done my selecting the appropriate type of construction method (e.g. timber frame, concrete, system building, etc...) and level of finishes - at which time a unit rate to floor area is applied. In both cases, they did not mention how expected costs related to incorporated, specific design and sustainable features - this creates a gap in the expectation of client required information to make comprehensive decisions.

The interviewed builders agreed with the perspective that fixed-price contracts are the best method for ensuring financial security for the client. They also both agreed that this style of contract requires a higher level of design detail and communication before construction commences - to mitigate their potential risks, which stem from 'grey' areas in the projects design. In addition, for clients who have the ability to place build quality over build cost, the cost-plus contract is the best method to achieve the highest possible result. Variations in the fixed-price contracts are managed by clear communication (frequent meetings, meeting minutes and updates on construction progress and budget) presented the cause of the price change (e.g. ground conditions, grey areas in the contract, documentation or requested by others, etc...), and the factors associated in deriving the cost variations.

Each client expressed that their preferred contract with builders would be a fixed-price contract. Each wanted greater security and control of the total construction cost. With Client 1 and 2, both concept designs were evaluated on cost with respect to total project cost: expected statutory, design (consultancy) and construction costs. This was completed by breaking the construction budget into trade packages. The project budget was broken down into the four categories and seven trade packages:

- Project Preliminaries: All statutory fees (local government, private certifier, long service levy, and Section 94a)
- Consultant: All consultancy fees (building designer, structural engineer, surveyor, geotechnical engineer, arborist, NatHERS certifier - if required, stormwater - if required)
- Construction Budget:
    1. Construction Preliminaries - environmental controls, builders margin, warranties, surveyor, scaffold, waste bins and plant hire.
    2. Structure - earthworks (bulk and detailed), concrete works (inc. driveway), OSD storage, structural timber, structural steel, and brick/blockwork.
    3. Services - electrical work (inc. PC items and PV system) and hydraulic work (inc. PC items, hot water, water tank and water treatment).
    4. Exterior Works - windows, insulation, sarking, painting, facade, tiling and roofing.
    5. Internal Works - internal linings, tiling, flooring, kitchen, cabinetry, painting, and decorative furnishings.
    6. Landscape - planting, footpaths, turf, clothes line, etc...
    7. Other - All unique additions to the builders contract.
- Miscellaneous: All unique expenditures to the project - outside of the builders contract (e.g. appliances, miscellaneous cabinetry, etc...)

Please note, this was completed using action research, and was undertaken during the time of the frameworks development, but before the interview dates by the researcher with Client 1 and 2. This was for two reasons, firstly because of the timing of the research progress and the progress of the case studies, and secondly because of the author’s experience in commercial construction budget management. In reflection, the breakdown structure noted above was effective in communicating the allocation and justification of project expenditures (especially

in terms of the added cost of sustainable features) to the client, and tendering and negotiating the final construction contract with builders. However, the initial unit rates used by the author to derive the construction budget during the design concept stage were incorrect, and not specific to the Illawarra residential building market. At this time, the author did not effectively account for the 20% to 30% variation in commercial unit rates.

Clients 3 and 4 explained that their project budget was initially stated to the building designer, and their designs were completed and approved (development application) before any budget 'checks' were completed. The clients construction forecast were both derived via unit rates applied to designed floor area - the unit rates were $2,000 and $1,250 for Client 3 and 4 respectively (including GST). This budget check was completed without any respect to design inclusions, i.e. materials, construction type (e.g. straw bale construction), and sustainable features (e.g. phase change material, double glazing, water tanks, water treatment, PV system, etc...). For both clients, the quoted build cost were between 50% to 100% more than initial designer estimates. For Client 3, this required a reduction of total floor area (by 30sqm) and a reduction of sustainable features - i.e. PV System and Water Tanks - for a retrospect installation. Unfortunately, Client 4 needed to stop the project, and re-design to suit their budget constraints. Table 21**:** Project Budget Vs Project Cost - Interviewee Responses outlines each interviewees response to how they manage their project budgets.

Table 21: Project Budget Vs Project Cost - Interviewee Responses.

Financial Management	
Interviewee	**Comments**
Architect 1	It was expressed that 'lump sum' or fixed price contracts are preferred. This mitigates financial risk for project overruns, and focuses key decisions back to cost - therefore helping to manage key objectives. Cost overruns are managed within a fixed price contract by 'Provisional Sums'. A provisional sum is an allowance within the fixed price contract for work to be completed. Generally, a provisional sum is used because an accurate costing could not be determined at the onset of construction (for example, excavation of rock). A provisional sum could be considered similar to a 'cost-plus' contract, but only for specific work activities within a fixed price contract, i.e. excavation of rock, it is unsure the amount of time and work it will take to excavate, an allowance (provisional sum) of '$5,000' has been placed within the fixed price contract, but final excavation of rock cost will be issued to the client (plus builders margins). Through experience, the '$5,000' is estimated, but the builder and subcontracts take no responsibility. Cost variations, to initial budget and fixed price contract are not considered as cost overruns, but as 'extras'. They are considered as extras as they are at the request/approval of the client, and not due to the inactions of the designer/builder.

<table>
<tr><td>Building Designer 1</td><td>The budget is a major player in the design and construction of a house, and has to be addressed at the first meeting, and considered during the entire design and construction process. At the design brief stage, the target budget it set, and therefore the road map for the design and construction method, i.e. the construction approach - contracts, project home, material/construction systems and custom builders.

Generally, for a standardise method to mass design and construct sustainable houses, the current form of 'project home' and 'custom' construction needs to change. A systems approach needs to be found that is adaptable to individual client briefs, i.e. a hybrid approach between the two typical forms of house construction. Project home builders have a low grade systems approach while custom builders are never going to be widely available.

Typically, building designers/architects only design and in instances quality control the construction. The construction management is held with the client and builder. This disconnect lends itself to several project risks, for example, responsibility of the budget, control of variations, and delivery of the house to the design intent. For a standardise methods, this needs to be bridged.

It was expressed that 'lump sum' or fixed price contracts are preferred. This mitigates financial risk for project overruns, but it requires finer detail within the design and quality management with respect to the allowances within fixed price contract. Cost plus is a great method for out of the ordinary designs and the client has the financial capacity to take the risk (only applicable to a small percentage of persons).

System builders rely on know/provide construction material systems to build with, e.g. insulated formwork walls and suspended levels. The scale of a 'system build' extends from a 'project home' at one end, to fully fabricated factory built houses at the other. Both have positives and limits to achieve project objectives.

Initial cost estimates are generated by quantifying material quantities from the CAD model and unit rates.

The interviewee stated that cost overruns are typically caused by something unexpected, something that could not be identified and therefore controlled. This generally happens during renovations projects. Geotechnical and ground water uncertainty embodies most cost overruns within new construction projects. In addition, the other significant cost overrun is client changes. If not managed correctly by the responsible parties (i.e. designer, builder, client), the budget will no longer be controlled.</td></tr>
<tr><td>Builder 1</td><td>Cost-plus contract best for innovating building, more easily allows for change, unique materials, building processes and high-quality of finishes. Key stakeholders must be involved in each decision, and cost variations expressed immediately against the 'new' anticipated total build cost - communicate the 'bottom-line'.

Fixed-price contract are best to manage cost, but need a high level of detail and communication before commencement. More time and effort must be invested during the design and contract stage.

Variations are managed by continual updates to the client, and/or designer. This typically happens every two weeks to ensure no surprises arise, especially from design changes.</td></tr>
</table>

Builder 2	Generally, the interviewee works with 'Fixed-Price' contracts. This is due to the nature of the works undertaken by the interviewee - i.e. project difficulty and the client's financial capacity. From the beginning, a 'Fixed-Price' is develop in conjunction with the Client, and where requested (by the Client) the architect/designer. This is developed by breaking the project down into each trade, and obtaining construction quotes. It is noted that this process is depended on the quality of the documentation, and communication between the builder and subcontractor to 'how' the house will be constructed - as this is directly related to how each subcontractor organises their quotes. Changes during construction are not considered as variations, a variation is rare and is only encountered when a work-action could not be anticipated during the tendering stage. Typically, budget 'overruns' are due to documented design changes - either before or after the works have been completed. Fixed-price contract are best suited when a design is 'pushing the boundaries', and the client has the financial 'freedom' to place build quality above build cost. This scenario is much less common to the typical, 'Fixed-Price' financial conservative approach.
Client 1	The project cost was managed by establishing an initial project forecast budget - a breakdown of all expected fees associated with completion of the home. The Client explained that they felt that this was a good approach, however, the Client feels that this budget needed to be continually scrutinised with the ongoing development of the design. The contract used was a 'Fixed-Price' contract, this contract type was chosen to better manage the construction cost. The process to develop the fixed price contract was more lengthy, and required more detail within the building design documentation. This also, ensured no variations during the construction of the project. Project overruns or variations were managed by ensuring a high level of detail in the documentation. The Designer documented a high level of detail within the documentation, that ensured the fixed-price contract was tendered consistently, and the fixed prices for the build were comprehensive before commencing.
Client 2	The total build budget was outlined at the concept stage of the project. This budget has been related, via sub-budget sums (for each trade package), back to a total estimated construction cost. The design process was 'loosely' governed by expected trade package costs. The construction will be completed via a fixed-price contract. We wanted a fixed priced contract to help manage, or reduce the risk of the cost during the construction process. The design is currently out for tender, the final fixed priced construction build is pending.

Client 3	The financial constraints were expressed and captured within the client brief by the building designer. The circumstances of the client relating to this constraint was to place an emphasis on comfort and liveability, and sacrifice internal finishes and furnishings. The building designer managed the cost by applying a holistic square meter unit rates (i.e. $#,###.00 / sqm to construct fully-finished house). During the management of expected construction costs, there was no justification for applied unit rates, nor a connection to proposed features with cost. With relation to the first noted surprises, the fixed-price construction quotes received by builders were approximately 50% greater than the building designers estimates. It is felt that a greater emphasis should be placed on budget estimates, and a more effective connection between cost estimates, justifications of features and the decision-making process. The client preferred a fixed-price contract over a cost plus contract. This is because their need for budget control is more important than their desire for a 'premium' finish. They faced difficulties finding the 'right' builder to suit their direction - a 'midway' point between a premium builder (typically cost-plus) and a project home builder. To bring the cost of the project in alignment with the financial constraints, the design of the project changed (reduced in size - retaining the same form and setout), and the foundation construction altered. In addition, key features (e.g. solar panels, driveway, etc...) have not been included in the main building contract, but can be added by the client at a later time.
Client 4	The project budget was set (design fees and construction fees), and communicated to the designer. The design and documentation was completed, but the result was a design that did not consider the Client's construction budget. The Client's modest budget required the project to stop when the financial constraint was not considered in the delivered design. The Client has now taken control of the design and construction of the entire project to ensure their budget is maintained. Project cost will be managed by breaking the project down into smaller deliverables to match their budget. This will lead to a slower construction, but a successful final result.

5.2.7 Building Performance, Sustainable Features - how they are selected and validated.

Incorporating sustainable features within a building development can be achieved with an increase in capital cost between 5% and 10% (Martinho et al., 2013, Josh Byrne & Associates, 2012, Gabay et al., 2014, Professor Deo Prasad, 2010), which heightens building performances - which can reduce and operation emission reduction between 60% to 80%. The Interviewees were unable to provide specific date or information that would clarify or verify the quantitative claims from the research. However, the design and building consultants still consider the incorporation an added benefit to the client - if the feature was feasible in their budget.

Architect 1 explains openly that this is a growing area in the housing market, and his firm is still up-skilling their staff in sustainable features - namely technologies and rating systems.

Currently, Architect 1 feels that there is no specific demand, and therefore need to conduct further building analysis and/or building performance reviews (i.e. energy and thermal modelling) outside of the state requirements - BASIX Certificate (Planning and Environment, 2014). Their firm relies on passive design best practices, outside of this skill-set, the firm outsources to an environmental consultant (ESD).

Building Designer 1 is a recognised environmental building designer, and therefore sustainable, low impact and efficient homes is the focus of their core business. Like Architect 1, Building Designer 1 does not consider quantifiable validation (reporting) important for two reasons. Firstly, because the client typically trusts the direction/advice of the designer (in terms of specifying key features (decision-making) and secondly because the client typically places a higher emphasis on design reliability, quality and personal features (kitchen quality) over potential expected pay-backs.

The two builder interviewees consider sustainable validation from a different view point. This could be because they are not engaged early in the design process, and therefore are not integrated in the concept and detailed design - i.e. specifying of insulations, windows, building form, technologies (e.g. PV systems, water treatment, mechanical units, etc...), etc... From the builders point of view, validation involves their construction processes. This incorporates their construction time, construction cost, construction quality, construction materials (specifically FSC/AFS (Forest Stewardship Council Australia, 2014, Australian Forestry Standard Limited, 2010), recycled content, and recyclable), low VOC and formaldehyde, and site waste minimisation. Contrast to the building designers, the two builder interviewees considered sustainability validation very important. They considered it important for two reasons, they are: to create a traceable history of lessons learnt (allowing for a closed-loop of lessons learnt and therefore continual improvement) and an evolving method of material improvement and selection, detailing and construction processes. It is felt that "...a similar validation is just as important to designers and architects, higher levels of validation will evolve better 'rules of thumb' in their designs, and design details" (Builder 1, 2014) (leading to a more effective construction).

Client 1, 2 and 3 contracted a 'sustainable building designer' to design and commission their homes. Each of the three clients emphasised two key items, firstly the trust in the designer to

deliver a more 'sustainable' and efficient home, and secondly the designer would validate all preconceived performances levels against specified sustainable features. Validation for these three clients was considered highly important, to justify their increase capital expenditure - 'why are we paying for it?'. In addition, Client 2 expressed that this should be 'part of the deal' when engaging such a professional. This is contradictory to the response from both interviewed Architect and Building Designer. Client 1 and 2 expressed that the decisions made around the sustainable features were conducted in a systematic methodology. Firstly, the design options was proposed in a holistic fashion, and their positives, negatives and cost were compared and weighted against one another. This led to a 'trail' of conscious thought and evaluation of considered and incorporated sustainable features. Client 3 describes their sustainable feature process differently. Sustainable features were presented to the client in a qualitative approach and without quantitative analysis. The client expressed that they trusted the designers summarised conclusion on the sustainable features that should be included. The client agreed, and progressed with the suggested sustainable features. However, once the tendering process ended, and market value for the construction of the designs were established, the scale of the home and incorporation of sustainable features were reduced to re-align the project cost with the project budget. Client 3 expressed that the sustainable features needed to be evaluated with installation cost, and ongoing costs - to allow for a more comprehensive decision-making process.

Client 4 engaged a building designer who had no prior experience in sustainable buildings, which required the client to propose and make decisions regarding sustainable features to their designer. This process led to a halting of the project, and a re-design of the sustainable, straw-bale home.

Table 22: Building Performance, Sustainable Feature - How they Approved and Validated.

<table>
<tr><th colspan="2">Sustainable Features</th></tr>
<tr><th>Interviewee</th><th>Comments</th></tr>
<tr><td>Architect 1</td><td>Currently, the interviewee and their associated firm are on a 'learning curve' and up skilling their staff in environmental techniques, technologies, methodologies, materials and approaches. Traditionally, they only considered building orientation and passive solar design as their basis for their designs.

Unless specifically requested by the client, the interviewee relies on BASIX to confirm validity and compliance of house performance.

It was expressed that there is no demand for further analysis of environmental performance, therefore leaving the validation in the custody of the designer/architect. Holistically, validation is considered important, but currently not considered with respect to environmental measures within their building designs.</td></tr>
<tr><td>Building Designer 1</td><td>Environmental features are presented to clients' and justified by demonstrating their merits and compatibility to achieving the client brief. How the environmental feature is presenting shall also be a consideration. For example, FSC timber has slightly increased cost of the construction, but discuss the point from managed forests against illegal logging. The clients 'notions' should be considered.

How important is validation. Most clients do not ask for validation. This is for two main reasons, clients typically trust the direction/advise of the designer and the added cost to produce reports. The interviewee presents validation in terms of payback period on the investment and diminishing returns, and achieving a higher than average NatHERS star rating ("eight stars is a good place to be").

BASIX used to be used to demonstrate an exceedance of standards. Currently, BASIX is not used at all, as it has lost its impact.

An additional note, the clients' notions also extend beyond financial payback. The reliability and quality of the features/home can have a higher value to the client then a quantitative 'expected' payback period.</td></tr>
</table>

Builder 1	It is felt that the term 'green' and 'sustainable' is being highly overused, and only used as a marketing exercise without any validation. There are different levels of validation, for example, to validate the buildings expected performance, and validate the construction process. From the interviewees point of view, construction validation is important for several reasons. Firstly, demonstrate how effective the construction processes were, gauge the overall success of the construction period, allow to learn from captured information - refine processes/methods, and as a marketing tool. Depending on the project, the level of validation changes. Typically, the following is captured: construction speed (with respect to construction method and materials), waste management (recycled content), up-cycled/reused material within the new building, review of energy, lighting, mechanical and water systems (cost, installation, warranties, effectiveness), environmental management. There was an emphasis placed on materials, their use, maintenance, recycled content and recyclability. It was expressed that the design and construction industry should develop 'best practice' or 'rule of thumbs' for delivering sustainable homes. With growing experience, rule of thumbs for constructing bespoke sustainable architectural homes are becoming refined (for the interviewee), but not widespread. Validation of the interviewee's previous and current projects allows a 'closed-loop' for lessons learnt, and an evolving method of materials, detailing and construction processes. It is felt that a similar validation is just as important to designers and architects, higher levels of validation will evolve better 'rules of thumb' in their designs, and design details (leading to a more effective construction). During the construction, no performance matrices are used. The interviewee has their own internal benchmarks, processes and validation methods. This is demonstrated at the interview stage, through captured validations and embedded in the presented construction cost.
Builder 2	The interviewee considers environmental features viable, and successfully adopted by the client when they can be examined against a 'Pay-Off Period'. It was expressed that other environmental practices are becoming common due to the nature of construction costs. For example, construction waste is inherently being separated and recycled because it is cheaper for the builder. The user of the home can impact the usage of the house. The interviewee states that the client (potential home-user) should be educated on the products and systems being installed. For example, a gas hot water system ignites every time a mixer tap is used, regardless of the duration of use and temperature of the mixture setting. The interviewee stated that validation is important as an industry, to continually develop products, methods and systems. But personally, the interviewee feels it is less important, and tried to keep build costs as low as possible.
Client 1	During the design process, sustainability/environmental was not presented as standalone 'features', but more as a set of 'targets'. For example, increasing energy efficiency (as much as possible) - demand & supply, and water conservation were considered as targets (performance indicators). Decisions were continually made, and adjusted, to produce an 'evolved' solution to best achieve these targets. It was expressed by the Client that they felt this approach instilled a conscious thought process, and justification for each decision made - throughout the design of the home. The client expressed that validation is very important because it justifies the capital investment - if it cannot be justified, 'why invest?'.

Client 2	Initially, material performances, building form, glazing, systems and technologies were discussed and 'temporary' approval was given to progress the iterative process of design. The final validation is waiting to be issued, and is expected to be issued upon an 'as-built' home. An additional aspect that was raised is the compliance (of installation), warranties and liability of materials and systems being used. It was felt that this is a key contribution to the decision-making process, and should be addressed. Validating environmental features and building performance was considered very important. If a claim, or goal is specified by the given professional they should achieve this, and prove through validation. This is felt to be part of the 'package' for engaging a sustainable design professional.
Client 3	Each feature that was presented came with a level of knowledge and understanding of how it integrated into the building - to work as an 'engineered' product. This also lead to an understanding of how to operate the home. This level of knowledge and understanding needs more education on the clients behalf to best aid in the decision-making process. The features were presented and justified in a qualitative method. Quantitative analysis and validation were not presented to the client, but assumed to be conducted to support designers stance for the proposed features. Linking this back to cost would have helped the decision-making process for the client. The client feels that typically, general people commissioning homes are not as engaging/immersed in achieve the environmental objectives of their project, and tend to be more conservative and traditional with respect to their expectations.
Client 4	Typically, the sustainable features for this project/design were given by the client, to therefore be incorporated by the designer. The Client in this case used their own 'rules of thumb' which they collated via their own research. The Client also had additional requirements/specifications for the designer to include (and expressed that the concept stage), e.g. a building envelope that embodies a passive design and would complement/take advantage of the straw bales. The sustainable features were not validated as they were incorporated at the request of the Client. This also left 'holes' in the design, i.e. the highly insulated straw bales were complimented with conventional BCA requirements for glazing, roof insulation and none-straw bale walls.

The mixed perception regarding building performance, sustainable features, and required methods and levels validation demonstrates the unbalanced match, within the key stakeholder groups, between the understanding of sustainability and how it is delivered within the current building industry.

5.3 Chapter Summary

This chapter presented the responses of eight interviewee responses with respect to delivery of sustainable houses. The interviewees were selected from the three key stakeholder groups involved in the delivery of residential houses: the Building Commissioner (i.e. the client), Architects/Building Designers, and Builders/Contractors. The prepared interview questions

(found in APPENDIX E: Interview Questions) were tailored to be open-ended and relate specifically to the three themes of sustainability, in conjunction with the lessons learn from Chapters 2 and 3.

From the interview results, there were notable similarities and differences between the three different stakeholder groups and individual interviewees. The findings have been categorised under the main interview questions.

- Sustainability: A sustainable home is the 'right' balance between the clients social needs (as expressed from the perspective of the client, i.e. form and function), financial constraints and the feasibility of various incorporated environmental/sustainable features. All client interviews expressed the need that the house be 'future proof', and evolve with their changing needs over their life-time in the house, and with the potential for future tenants. This aspect was not expressed or discussed with any of the professional interviewees.
- Project Failure: The professional interviewees expressed a similar level of importance towards four key project failures: client satisfaction, project 'completion' (at the perspective of the stakeholder), achieving project outcomes (perceived value), and stakeholder profitability (expressed by builder interviewees only). In addition, the professional interviewees did not consider partial project failures. The difference was noted between the clients and professional stakeholders. Clients placed a high emphasis on project budget control, and every interview client experienced a partial failure in the alignment of their social needs, sustainability features and budget management. The professional interviewees considered the final, constructed result as the defining measure of success - not the process.
- Project Risk: The four professional interviews revealed a similar perception to project risk. The considered risks were: project budget, accurately capturing client objectives, delivering project objectives and construction execution risk. The main difference between the results was the emphasis placed on each risk. The design professionals considered client objectives and delivery as the highest risk (and evaluator of total project success), whereas the building professionals considered budget and construction (e.g. safety) as the highest risk.
- Stakeholder Management: A commonality in interview responses can be drawn with regards to the design, and the stage at which the building contractors are engaged.

Each professional interviewee believes that the current practice is adverse to delivering an alignment of stakeholder objectives - that can lead to conflicts. The design and construction professionals feel that the builder should be involved in the design and cost planning for the project. It is stated that this would manage financial risk (in construction), design detailing, and an open communication between the three key stakeholders at the commencement of the project.

- <u>Client Objectives:</u> The main similarity between the design professionals was the importance placed on a comprehensive client brief (in terms of social requirements - form and function). The interviewed builders considered the construction of the design with respect to one key client objective - construction budget. The importance of the client brief was unanimous, but the type of information and method of collection varied between the design and construction professionals. For the designers, the obvious deviation was with respect to what information was collected and how it was synthesised. The builders were consistent in their responses, but were dissimilar to the designer responses. The builders did not collect client objectives, but 'assumed' their requirements were reflective in the design - therefore requiring their primary objective for the client was to refine the design to suit their budget. The client brief needs to be developed at the commencement of the project, and it is the responsibility of each key stakeholder to ensure they are delivered through appropriate project planning.
- <u>Decision-making:</u> There were three prominent similarities in the interview responses. The design professionals did not have a defined approach to project decision-making, and relied on their intuition with respect to the working relationship with their client which lend itself towards an ad-hoc decision-making process. The building professionals separated decisions between 'construction decisions' (e.g. decisions that affect the operations of the construction site - building delivery) and 'design, compliance and budget decisions'. Each client through that this was critical in the design development stage. Communication and documentation should be used to make informed decisions that affected the design and construction. For a client to make informed decision, the engaged professionals need to ensure that they provide a high level of information - especially toward innovative sustainable features.
- <u>Budget Management:</u> Each interviewee expressed the best method to manage the construction cost is via a fixed-price contract. The total project budget should be

managed during the design development stage to ensure the initial project budget matched the construction costs. It is the responsibility of the building designer to ensure design reflects budgetary constraints.

- <u>Building Performance/Sustainable Features:</u> There were no noted similarities between the different stakeholder groups. However, each stakeholder group was generally in alignment. The interviewed designers did not consider validation as an important aspect of their design process. The builders considered different aspects of sustainability - i.e. waste minimisation, recycled materials and construction processes, in addition both builders considered validation of their work as highly important. Each client considered validation has a key ingredient in the decision-making process for sustainable features in balancing expected building performance. Achieving desired building performance and sustainable features was met with mixed perceptions. Each client interviewee expected validation for aspect of the design and construction of their house, (by social - e.g. client brief, form/function/aesthetics, financial - e.g. project budget, pay-back period, and environmental indicators - e.g. energy performances, thermal modelling, LCA, water analysis) with respect to the projects objectives. Whereas the designers relied on their 'rule of thumb', and passive design principles (without validation).

The findings within this chapter indicate that there are differences and similarities between the key stakeholder groups. The two main differences are the *need* for validation of sustainable features between the designers and the client/builder stakeholders, and who is responsible for managing the project budget during the design and construction phases. Many of the differences can be attributed to an insufficient alignment of stakeholder objectives with overall project objectives (client brief). Aligning the designer's and builder's objectives with project will ensure building requirements, performance outcomes and the project budget are managed and accomplished through effective collaboration and informed decision-making. Aligning stakeholder and project objectives can also reduce associated implementation risk to the residential development.

CHAPTER 6. PROJECT MANAGEMENT FRAMEWORK FOR DELIVERING SUSTAINABLE RESIDENTIAL DEVELOPMENTS

6.1 Introduction

This chapter presents the project management framework for delivering sustainable residential developments - titled 'ProSustain'. The ProSustain framework aims at providing a workable guidance to deliver sustainable residential developments by considering a tailored set of sustainable objectives (refer to Chapter 2), an appropriate stakeholder management structure (refer to Chapter 3), and an informative decision-making protocol (refer to Chapter 3 and 5). In addition, the framework will be based on project management best practices outlined by PMBOK (PMI, 2008). The framework does not indent to provide defined processes, methods, boundaries or techniques to deliver residential developments, but prescribes the approaches in their given contexts and their innate interconnectedness. Understanding their individual importance and interrelated nature is central for initiating, planning, executing, monitoring & controlling and closing a project successfully - and sustainably.

6.2 Delivering Sustainable Houses in Australia

Delivering a sustainable home is an achievable goal, and has been demonstrated around the world (Wallpe et al., 2012) and in Australia (Team UOW, 2013, Josh Byrne & Associates, 2012). Delivering sustainable residential developments in Australia requires knowledge in three areas: project management, sustainability, and government legislation, guidelines, standards and approval processes.

The relationships between the three sustainable development knowledge areas are outlined in Figure 27 (page 126). This figure outlines the key knowledge dot-points associated for each sub-group. Each dot-point is written from the perspective of that specific knowledge area and sub-group, e.g. Residential Development; Risk; these key knowledge points are at the perspective of the government. The sustainable development knowledge area is primarily at the perspective from the client, and secondly at the projects associated stakeholders.

The project management (PM) knowledge area consists of five processes, which are used to initiate, plan, monitor, execute and successfully conclude the project objectives. Within each process, are tasks that are required to ensure project risk, budget and stakeholder management are effectively controlled. The PM aspect of the framework relates to sustainability by the planning and execution of sustainable objectives, outlined during the project initiation. This area of the framework will be explained in more detail in Section 6.4.2.

The sustainability knowledge area consists of the three themes of sustainability - social, financial and environmental (McCarthy and Rasekh, 2013, Sarkis *et al.*, 2011). For a project to deliver a sustainable result, each theme of sustainability needs to be considered and balanced against one another's respective sustainable objective (Zhang and London, 2011, Sarkis *et al.*, 2011, Dair and Williams, 2006). The sustainable objectives are the critical starting point in the projects initiation, and consequently final successes (PMI, 2008). Because ProSustain has been positioned to deliver successful sustainable residential developments, the projects' objectives are aligned with the project commissioners objectives. Therefore, each project objectives relating to the triple bottom line is with respect to the client objective.

The residential development knowledge area includes the information related to the typical approval process required for domestic developments with local government. This is an important aspect to ProSustain because the approval processes link directly with key project management milestones. The residential development knowledge area is made up of five levels, in descending hierarchical order they are: governance, risk, standards, utilities and knowledge/skill. The governance refers to national, state and local legislation, as well as their enforcing bodies - typically local government and private certifiers. The development of legislation is backed by risk profiling. This means, the building legislation and approving authorities, like all business practices, instil associated risks. In this case, the risk for approval authorities are building development safety, structural integrity, environmental impacts, resources, utilities, town planning and local economies. The National Construction Code (NCC) (Australian Building Codes Board, 2015), the applicable Australian Standards - for example: AS1720, AS2870, AS3000, AS3600, AS3959, and AS4100 (Standards Australia, 2015), the Local Environmental Plan (LEP) and Development Control Plan (DCP) (specific to each local government) are the key documents that ensure developments are 'risk-free' and

compliant. All relevant Australian Standards can be found in APPENDIX N: Relevant Australian Standards To Domestic House Design and Construction (page 261). In addition they represent the specific design requirements for each local government and specific design requirements for designated areas within the respective local government jurisdiction. Utilities include all associated services supplied to domestic residencies: water, waste water, electricity, gas, and telecommunications. This section includes a new set of planning and construction standards that are mandated by the service providers. The final dot-point is knowledge and skill.

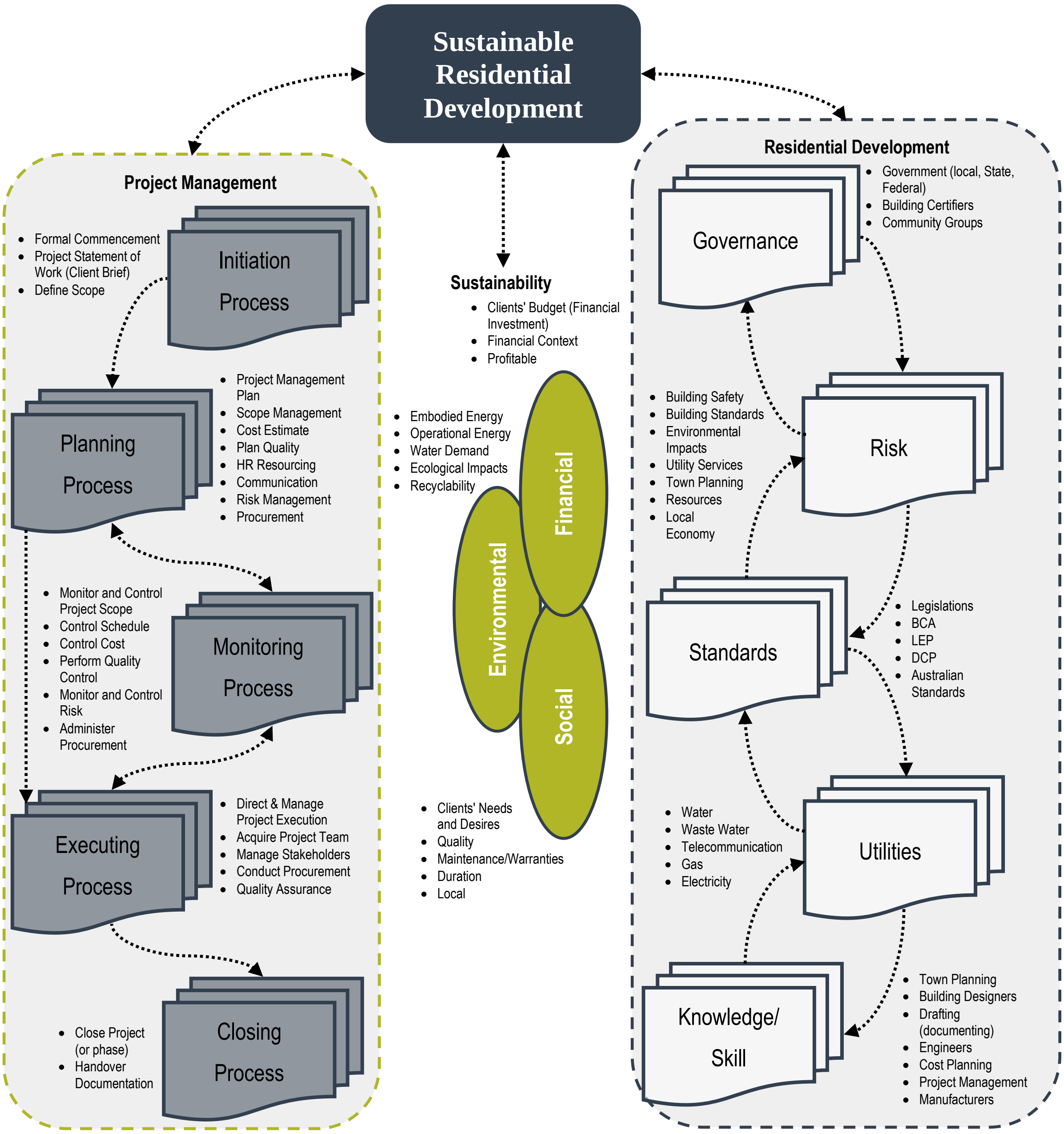

Figure 27: Relationship Between Project Management, Sustainability and Residential Development.

6.2.1 Building Development Life-Cycle

Building developments typically go through several stages over their life time. For this research and ProSustain, three are considered significant: Design, Construction and Operation. In addition to the building development stages, there are two compliance (legislative) stages for a residential development project: Development Consent (Development Application - DA) and Construction Certificate (CC). The DA and CC approvals are key milestones in a developments life-cycle, and are in alignment with the first two building development stages. Australian developments are carried out accordance with Environmental Planning and Assessment Act 1979, which defines development as:

- The use of land
- The subdivision of land
- The erection of a building
- The carrying out of work
- Demolition, or
- Any other matter controlled by an environmental planning instrument.

Throughout the building development stages, the use of validation is important to ensure project deliverables are monitored and achieved. Various strategies are required to validate the different project objectives during the development three stages, and should be described in the project management plan and implemented during the delivery of design and construction outcomes.

6.2.1.1 Building Design Outcomes

The design outcomes are typically staged over three milestones: Concept Design, Design Development, and Detailed Design. The design stage includes all design disciplines, i.e. building design, structural design, services design and ESD consultant (typically not applicable in residential developments). The Concept Design stage shall also capture the objectives of the development. Typically, design details are deduced from collaboration between the construction constructor (and on occasion subcontractors) and the building designer/architect.

Development Consent

Development consent (DC) is the first formal milestone required for any development project to progress. The DC milestone ensures the proposed development intent complies with national and local provisions and standards. DC is achieved through the submission and approval of a Development Application (DA) and any subsequent applications related to building or construction work. Each submission required for development consent is assessed under section 79C(1) of the NSW Act.

Typically, DA approvals are subject to the following provisions:

- The suitability of the site for the proposed development
- Public interest survey
- Likely effects of the development on the natural and built environment
- Likely effects on local social and environmental conditions
- Local Environmental Plan (LEP) provisions and regulations
- Local Development Control Plan (DCP) provisions and regulations
- National Construction Code (NCC) guidelines
- Environmental management plan, in alignment with location regulations and DECC requirements

DA drawings and additional information provided with the DA has to be presented in detail to the governing body (local government) before consent may be provided. If the proposed development is in alignment with the Act and complying with development provisions, DA consent is typically issued 45 days after lodgement. Exemptions to DA approval may be considered if the conditions of the development fall meet the standards outlined in the 'Exempt and Complying Development Policy' issued by NSW Department of Planning and Environmental (Planning and Environment, 2015).

6.2.1.2 Construction

The construction of a building is typically divided over several key milestones: Site Establishment (including site preliminaries), Earthworks, Structure, Fit-out, and Practical Completion. The construction must be carried out by a licence builder. Design changes at this stage in a developments life-cycle increase construction costs and construction time. The completed building shall be warranted by the builder and associated contractors for a

minimum of 7 years (Department of Fair Trading, 2014). Depending on the house design and building site condition, typical construction duration is between 6 to 18 months.

<u>Construction Certificate</u>

After development consent has been provided, and before construction can commence, the development needs to be issued a construction certificate by local authorities. A construction certificate (CC) verifies that:

- The detailed construction plans and specifications of the development are consistent with the development consent and comply with the National Construction Code of Australia
- All required contributions and fees have been paid
- All development consent conditions have been met.

Note: Exceptions DA approvals, a complying development certificate, is issued by the private certifier.

6.2.1.3 Building Operation

The operation of a house needs to be considered during the design and construction stages, and form part of the design and construction outcomes. Over the operation life-cycle of a house, the operational demand represents a large portion of the overall energy, gas and water demand (Saman et al., 2012, Fay et al., 2000). In Australia, operational energy for houses can be predicted by using numerous energy modelling software packages. The national certifying body is NatHERS (2014), NatHERS outlines a standardised protocol and list of assumptions for conduction energy modelling (Office of Environment and Heritage, 2014). Linking how the design, materials and details effect operational energy should be considered during the development of the design, and cross referenced to the life-cycle analysis.

6.3 Key Implementation Factors for Sustainable Residential Developments

Sustainable objectives, stakeholder management and decision making are three important factors that need to be considered to ensure a functional framework.

6.3.1 Sustainable Objectives for Residential Developments

Sustainable Objectives (SO) represents a key measure of sustainability for a building development project (Zhang and London, 2011). The SRDPM framework utilises a tailored number of key sustainable objectives to help development of the client brief, and manage and validate sustainable development outcomes. The SO have been divided into the three themes of sustainability - and not specifically environmental. Sustainability and environmental are not the same thing. Sustainability is the need to considered multiple variables across the three core aspects of modern society to result in an optimised solution. Therefore an environmental solution may not be sustainable because it has not been considered against other *financial* and *social* factors. Therefore, under each sustainably theme, key sustainability objectives are expressed - from the clients point of view. Table 23 outlines sustainability objectives that were developed by the author with respect to the finding in Section 2.3 (page 10) and action research during the implementation of the practical case studies in Chapter 7.

Table 23: ProSustain: Sustainability Objectives

Themes of Sustainability	Sustainability Objectives
Economic Objectives	To enable business to be efficient and competitive
	To reduce operational cost
	To remain within budgetary constraints
Social Objectives	To adhere to ethical trading and fairness-at-work standards policies
	An increase in yearly thermal comfort
	To provide housing to meet needs of the client
	To integrate the development within the locality
	To conserve local culture and heritage, if appropriate
Environmental Objectives	To minimise the use of resources
	To minimise pollution
	Reduce operational demand (energy, water, waste water, gas)

To ensure correct application of the sustainability objectives, they should all be considered in the development of the client brief - during the project initiation process. During this process, each objective needs to be quantified and/or qualified, and coupled with key performance

indicators. The key performance indicators allow the project manager, and management team to validate the progress of the residential development. In addition, this brief needs to contain the projects hard, compliance and site constraints and project contingency.

Typically, quantifiable objectives are validated with key performance indicators by comparing the project design and construction against a base-case. This can be achieved by benchmarking against a national standard (e.g. NatHERS star level), and/or a comparable NCC compliant design of the same structure (i.e. without the sustainability features).

6.3.1.1 Project Validation

Project validation is a key aspect to the project management 'Monitoring Process' (MP). Validating can only be achieved with defined project objectives, accurate project data, validating method and a benchmark. The project manager and project team needs to ensure that the project objectives are defined within the client brief, and the MP is developed and effectively implemented. The MP shall also contain monitoring frequency, responsible individuals and reporting.

Validation methods need to be described in the project management plan, and should be agreed upon by the client, project manager and project team. It is recommended that selected validation methods be recognised, authorised by a third party, and work within the implementing organisations operations. Several methods of environmental validation were expressed in Section 4.4.3 (page 72). Specific methods for financial and social validation methods are outside the scope of this research, and ProSustain. Financial and social validation methods should compliment ongoing organisation operations.

6.3.2 Key Residential Development Stakeholders

Residential development stakeholders represent the key individuals and organisations involved in the delivery of residential developments. Outlining, and defining a project manager, project teams and stakeholder map with defined boundaries is instrumental in the management and delegation of project work. ProSustain relies on the appointment of a project manager. The project manager shall be selected by the Project Sponsor (i.e. the

Client), and empowered through contract. The project manager can either be, the client, the lead designer or the builder. This is signified during the project 'Initiation Process'.

The four key personnel are: the Project Sponsor (i.e. the client), the Project Manager, and the Functional Managers - the Lead Designer and Builder. There are two working team which are led by each Functional Manager. The Functional Managers manage the delivery teams, which comprises of internal staff (employees of either the designer or the builder) and external staff (employees of external companies that are contracted to either the Lead Designer or the Builder).

Figure 28 outlines the mapping of the residential development stakeholders. In addition to the mentioned stakeholders, and working team is the 'Local Authorities & General Public'. This group represents the key stakeholders outside of the project implementation and delivery team, while still containing external influence on the project delivery.

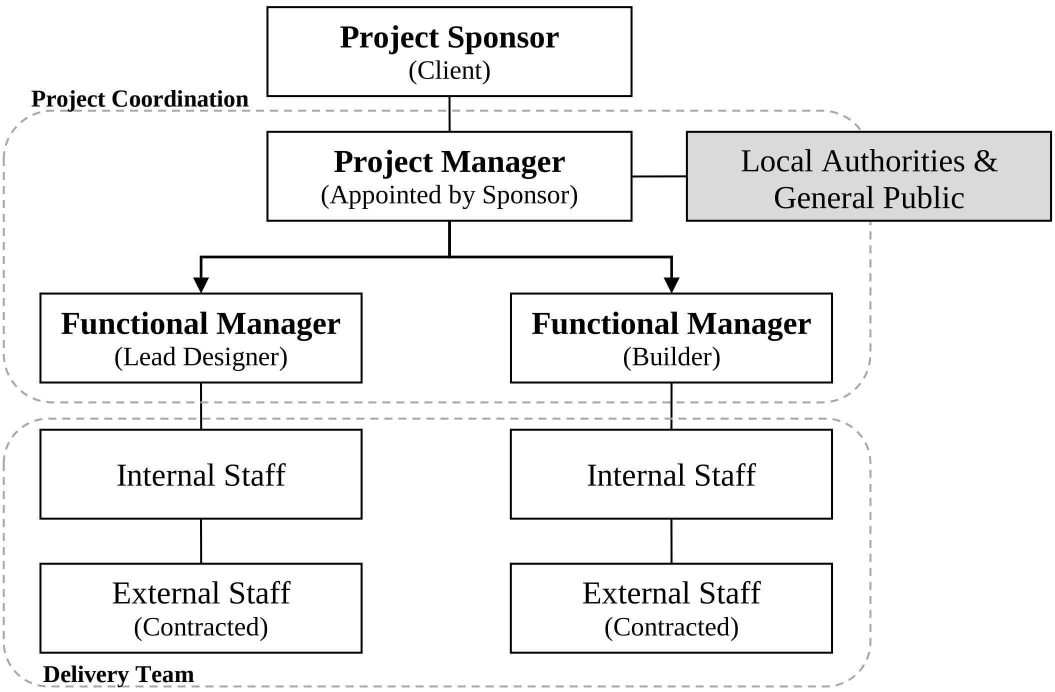

Figure 28: Key Residential Development Stakeholders

Project Sponsor

A project sponsor is a person, family or group that provides the financial resources for the project. The project sponsor leads the project through the selection process and engagement of key stakeholders until formally authorised, and therefore they play a pivotal role in deriving the project scope, objectives and direction (PMI, 2008). In the context of this ProSustain framework, the project sponsor is the client.

Project Manager

The project manager is assigned by the project sponsor, and can either be: the client, lead designer, builder, or other person. The role of the project manager is to be flexible and adaptable with a good judge of character, strong leadership and negotiation skills backed with grounded project management knowledge (PMI, 2008). The project manager is responsible for the development of the project brief, project management plan (and related plans, e.g. financial, risk, communication, monitoring, etc), monitoring project progress with respect to objectives, time and budget, and reporting to project sponsor.

Functional Manager

Functional managers are key individuals because they play a management role in the delivery of project outcomes (design and constructions). The two core functions within a residential development are in building design - 'Lead Designer' and construction - 'Builder'. They must manage their internal staff and external stuff (i.e. contracted work). All staff that report under the functional managers are considered part of the delivery team.

- Lead Designer

The lead designer is assigned by contract, using an evaluation process (tendering) involving the project sponsor and project manager (generally, they are the same person - i.e. Project Manager and Lead Designer). The lead designers roles and responsibilities shall be outlined in the contract documents between their organisation and the project manager/sponsor. Typically they are responsible for championing the developing the client brief, design concept, detailed design, and design compliance.

- Builder

The builder is assigned by contract through a tendering process, based on developed project documentation (i.e. tender documentation, drawings, specifications, and standards).

Generally, the builder does not join the coordination and delivery team until part-way through the detailed design. The builder is typically responsible for the safe, quick and cost effective construction of the proposed building design.

<u>Delivery Team</u>

The delivery team includes internal and external (by contract, conducting a portion of the works) staff that are associated with either the lead designer or builder. The design and construction delivery team should work closely together to ensure harmony between design intent and construction materials, methods and practices.

- Internal Staff

The internal staff are employees to the organisation that is directly contracted to the project sponsor for the delivery of either the design or construction portion of the project delivery.

- External Staff

The external staff are employees of organisations that are contracted to either the lead designer or the builder, to supplement their contractual commitment to the project sponsor. They are typically consultants (e.g. structural engineers), subcontractors (e.g. concreters), and suppliers (e.g. window manufactures).

6.3.3 Decision-making Protocol

The Decision-Making Protocol (DMP), shown in Figure 29**:** ProSustain Decision-making Protocol represents the identified need from the findings in Chapter 5. The acknowledged need for a DMP stemmed from client requirements to feel confident in their decisions, especially with respect to validating the inclusion of decision-making. The DMP applied to any person involved in the project coordination and delivery. In addition, the DMP was developed in collaboration with the conducted action research during the application of ProSustain. The aim of this DMP is to provide a clear delineation between decisions that be concluded independently, locally and by others. The determination of the decision/s importance is at the discussion of the individual. An independent decision can be made by the individual, a local decision can be made within the Delivery Team (in collaboration), and a decision by others shall be concluded by either the project sponsor, project manager and/or the functional managers.

Regardless of the context, the decision protocol remains consistent and is applicable for use by all involved individuals and organisations. It is the responsibility of the project manager that the DMP is implemented and managed. The DMP starts with the assessing individual, who should assess the project objectives, and how they could be effecting by this decision/s, and how will the resulting decision/s be measured, validated and benchmarked. Depending on the significance of the decision, the individual needs to determine who needs to be the custodian of this final decision/s. It is the responsibility of the initial decision/s identifier (and potentially extended team) to collate the required information to ensure an informed decision by the decision maker. It is key that the collated decision information reflects past decisions made and their effect on other, secondary project decisions. Finally, the recording of all project decisions. This allows for a closed-loop in the evolution of the projects decisions. The decision making protocol is outlined in Figure 29.

As indicated, this section of the ProSustain framework was incorporated due to the findings in Chapter 5, but was developed using action research from implementing the remainder of the framework on to real-life case studies. Therefore, this section requires further evaluation, and validation.

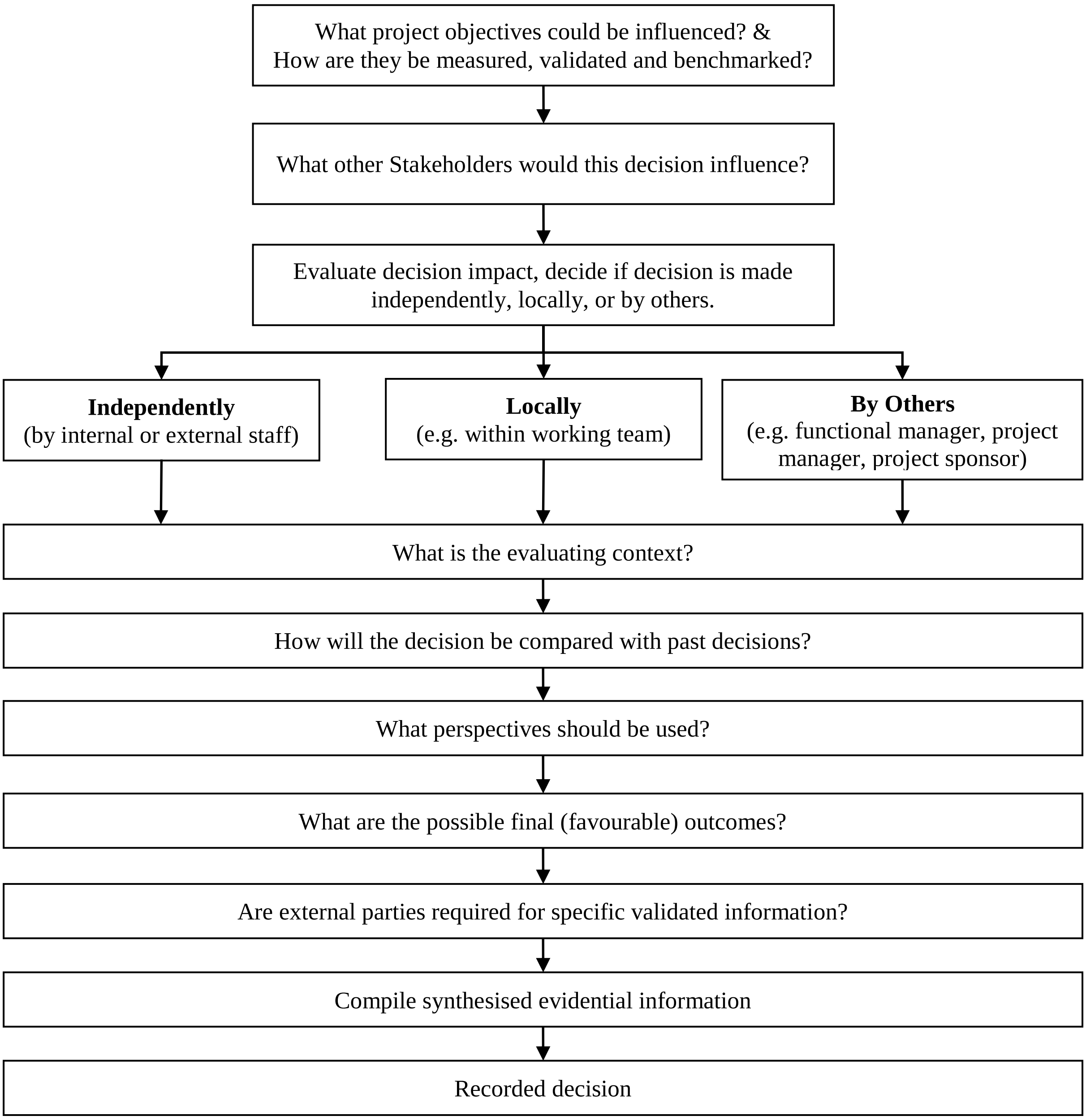

Figure 29: ProSustain Decision-making Protocol.

6.4 Sustainable Residential Development Project Management Framework: Life-Cycle, Processes and Influences

The sustainable residential develop project management framework is based on project management best practices outlined by PMBOK (PMI, 2008). The framework does not intend to provide defined processes, methods, boundaries, tools or techniques that need to be strictly followed to deliver residential developments, but prescribes the approaches and considerations in their given contexts and their interconnectedness.

6.4.1 Integrating Sustainability in Projects

Sustainability is integrated through the evaluation of application of sustainable objectives (refer to Section 6.3.1), which establishes the commissioning document for the project. At this time, the commissioning document must also consider the effects of outside influences on the project. This refers to governance placed (national, state and local compliance requirements) on residential developments.

Sustainable integration also includes the making of choices in terms "...of resource allocation, making trade-offs [among competing delivery method] alternatives, and managing the interdependencies among the project management knowledge areas" (PMI, 2008). Figure 30 outlines how sustainability, residential development, and the tailored project management knowledge areas are integrated.

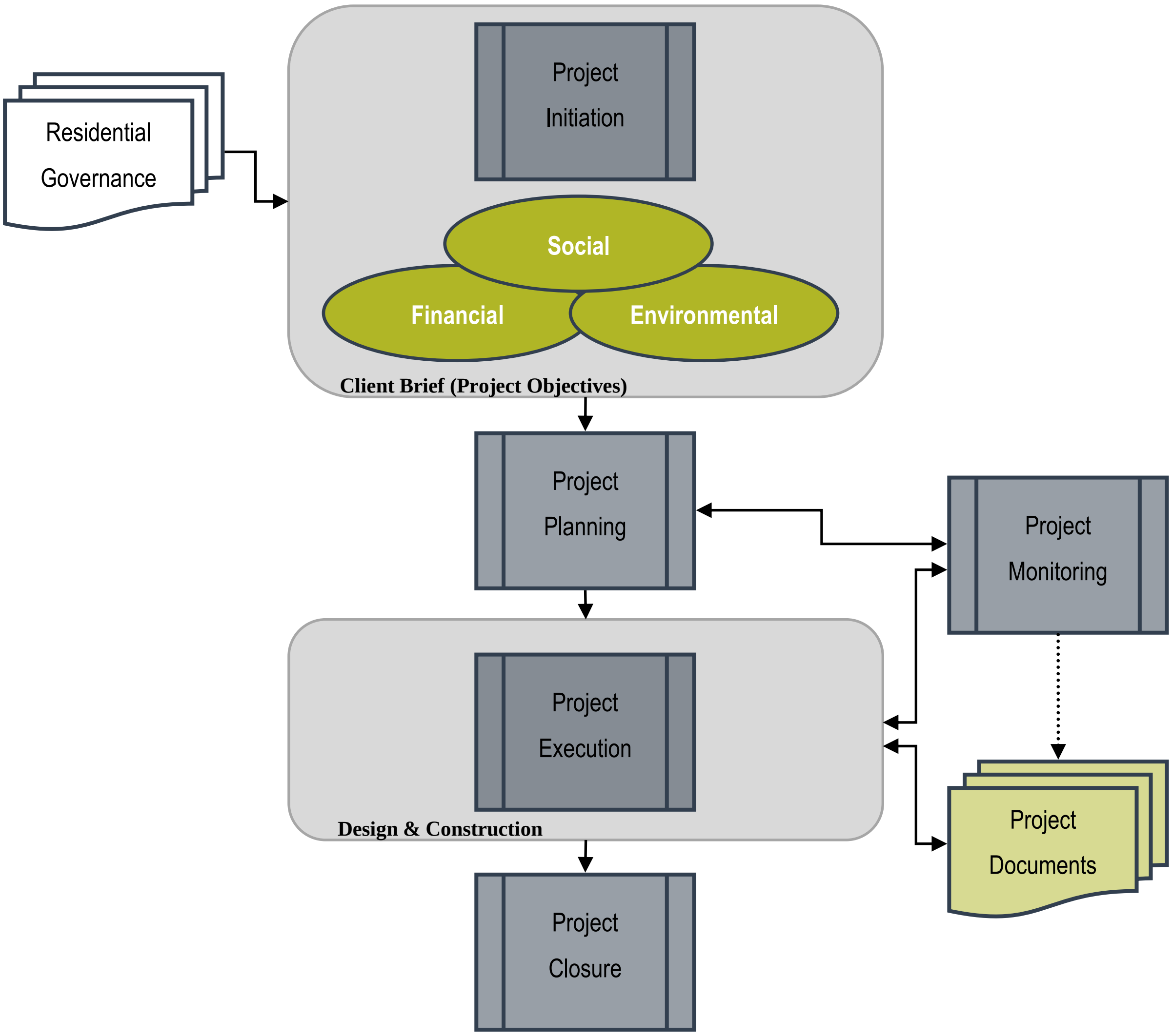

Figure 30: Sustainable Development - Project Management Integration.

Each project management knowledge area contains specific considerations and deliverables, which add to the ongoing development of the project. The integration figure outlines how each are connected, and incorporated to delivering sustainable objectives.

6.4.2 Project Management and Building Development Life-Cycle

The life-cycle of a project is a collection of sequences, that in most cases is the overlapping of project phases, and therefore project actions needed to deliver project objectives (PMI, 2008). While every project has a defined beginning and end, each project will contain a unique set of deliverables, activities and actions, specific to the delivery of the respective project objectives. The project management life-cycle in this framework provides a basic illustration that links the five project phases/processes with the projects life-cycle. Figure 31 outlines the typical time-line of applicable processes during the building developments life-cycle.

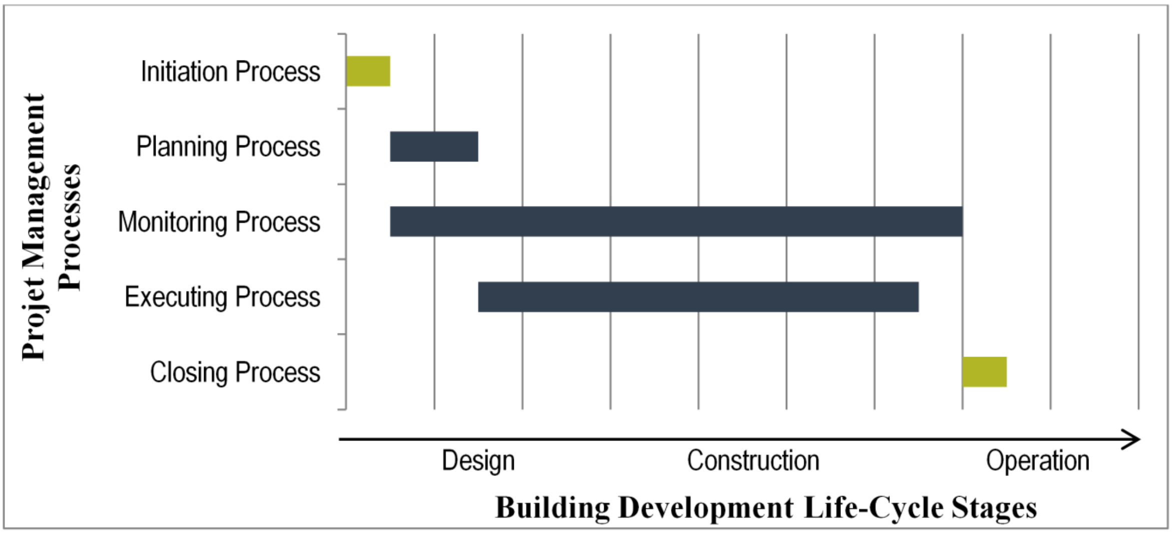

Figure 31: Project Management and Building Development Life-Cycle.

The initiation process commences the project and outlines the projects objectives that are used in the planning process and concept design development. The planning process is coordinated at the beginning of the design stage, and sets the agenda for how the remainder of the project will be managed until project completion. The monitoring process is implemented during the entire project planning and executing process, to ensure project compliance with project objectives. The execution process embodies the design and

construction deliverables, this includes taking into consideration the operation period (building performance) of the building development. The closing process signifies the conclusion of the project, and is represented at the operation stage of the developments life-cycle.

6.4.2.1 Initiation Process

The initiating process group consists of the deliverables, activities, information and actions needed to define and commission the project. Within the initiating process group, the project scope, project objectives, financial resources, project timeline and project boundaries are defined. The internal and external project stakeholder that interact and influence the outcome of the project are identified (refer to Section 6.3.2). During this time, a project manager shall be pointed. This collated, synthesised and approved project deliverables is then named the 'Client Brief'.

The client brief is significant to the overall planning, executing, monitoring and closing of the project. The client brief needs to contain the following:

- Project scope: Client requirements (desires and essentials)
- Defined, measureable sustainable objectives (refer to Section 6.3.1)
- Project constraints (legislative, site, and financial)
- Project time-line
- Stakeholder map (refer to Section 6.3.2).

Involving the client and other key stakeholders (government, potential designers and builders) in this "...process generally improves the probability of shared ownership, deliverable acceptance, and customer and other stakeholder satisfaction." (PMI, 2008). Figure 32 represents the interplay between the various documents, information, stakeholders, actions and deliverables required to commission a project - and deliver a sustainable residential development.

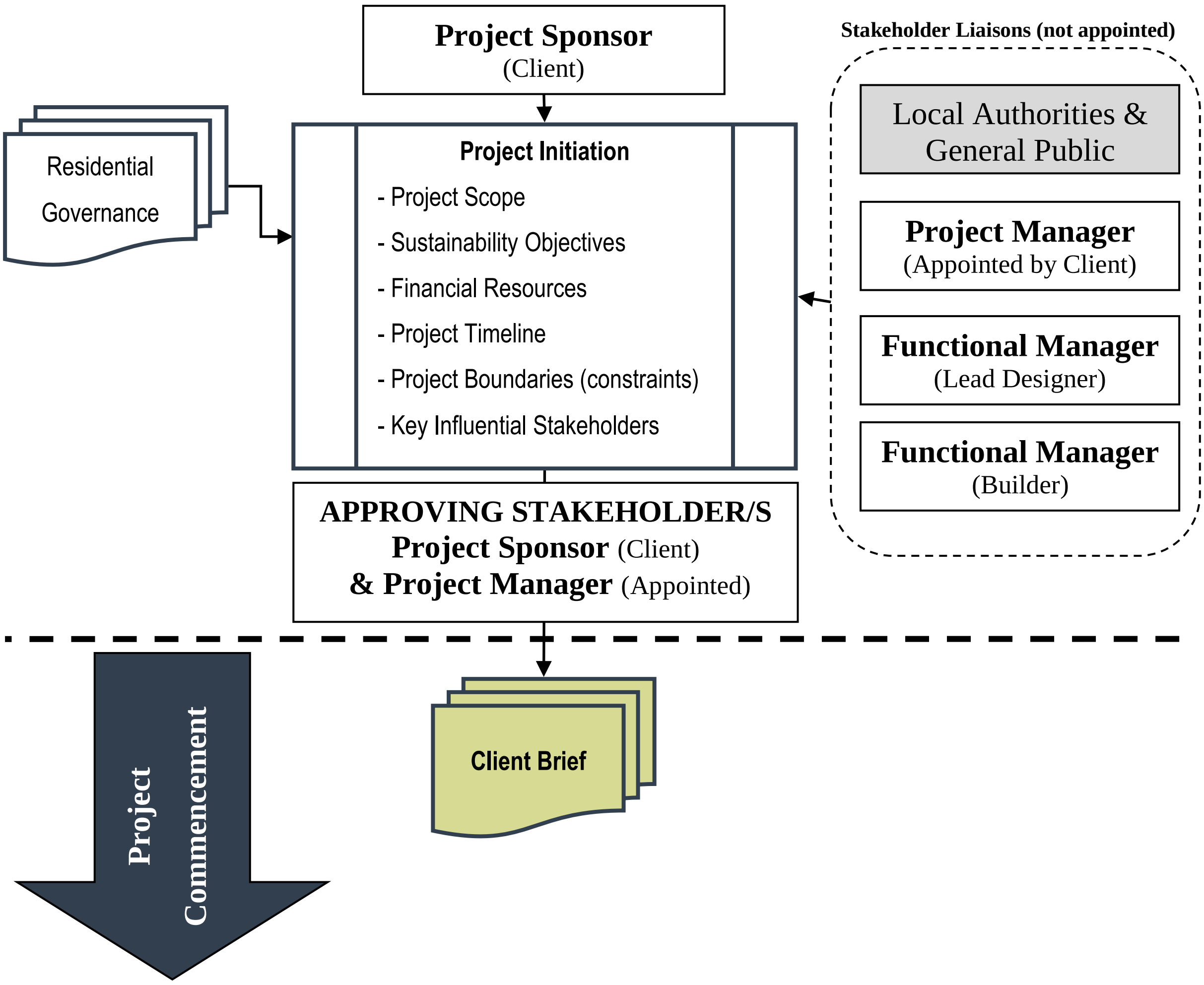

Figure 32: Project Initiation - Sustainable Residential Developments.

6.4.2.2 Planning Process

The result is the development of a project management plan, which becomes the primary source of information for how the project will be planned, executed, monitored and controlled and closed (PMI, 2008).

Figure 33 outlines the three key inputs needed in developing the project management plan. The three inputs are the client brief, the project stages, and the organisational processes and assets (of the project managing organisation).

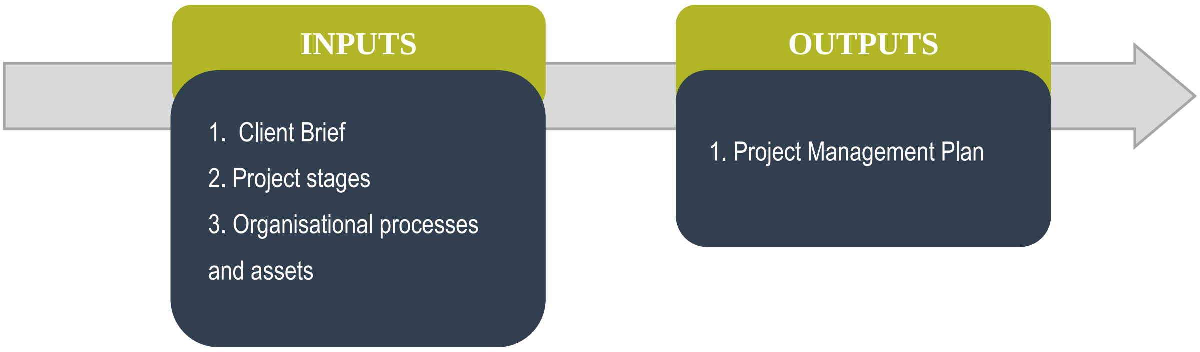

Figure 33: Project Planning Process: Inputs and Outputs.

For the project management plan to be effective, it should contain the following (refer to PMBOK for a more in-depth understanding for developing a project management plan (PMI, 2008):

- Work break-down structure: Define all project activities, sequencing and resource allocation.
- Project timeline: Estimate activity durations, schedule develop activities, and track progress.
- Budget management plan: Estimate project cost for each work activity, and project associated expenditures. Develop project budget (an aggregate of estimated project costs), to establish an authorised cost baseline. Refer ongoing project decision back to project cost estimates.
- Quality plan: Developing the quality plan is the process of identifying the quality requirements of the project - i.e. standards of project delivery with respect to design, projects, systems and documentation. This quality baseline is developed in conjunction with the client brief.
- Monitoring & control plan:
- Communications plan: The communication plan is developed with respect to the project stakeholder information needs and organisations structures and processes. The communication plan shall enable to needs of implementing the decision-making protocol.
- Risk management plan: This plan defines the process of risk identification, evaluation (risk assessment), mitigating and monitoring. This plan considers risk from all facets of the project including: project scope, cost planning, schedule management,

procurement, communication, decision-making, stakeholder management, enterprise safety and environmental factors (refer to Section 3.1.3).

- Procurement plan: The procurement plan is the process of documenting project purchase decisions, specifying the approach, and identifying potential sellers.

6.4.2.3 Monitoring and Control Process

Verification of project work requires the process of monitoring, reviewing and regulating the process to ensure the project meets defined outcomes (PMI, 2008). The client brief provides ProSustain with the objectives, conditions and constraints for which the project can be monitored, validated and evaluated. The evaluation and validation methods and tools are used to track the delivery of project outcomes during a projects life. The methods and tools can vary from project to project, but once selected become part of the project management plan. The selection requirements for the evaluation and validation methods and tools used is at the discretion of the project manager, and associated organisations processes. During the selection of appropriate methods, several factors should be considered:

- The Client Brief (sustainability objectives, project conditions and constraints)
- The culture of the implementing company
- Current company assets and tools (company processes derived from either software, hardware and/or systems)
- The project specific requirements
- The validity of the evaluation method and tool

Figure 34 outlines the approach that should be considered when selecting an evaluation tool for each indicator and objective for each stage of the project. The evaluation tool needs to be specific and effective to both the indicator and objective to ensure validity of measure.

Figure 34: Monitor and Control Project Work: Inputs, Methods and Outputs.

6.4.2.4 Executing Process

The executing knowledge group, is the group of processes preformed to complete the work defined in project management plan to satisfy the client brief (PMI, 2008), and with respect to on-going work milestones - i.e. design compliance with sustainability objectives and construction in compliance with drawings and specifications. During the execution of the project objectives, monitoring results may require planning update and a readjustment to the project conditions. This could include changes to expected activity durations, changes in resourcing, and unanticipated risks. Each eventually requires the project manager to develop appropriate responses with project history, and an evaluation of outstanding project deliverables with respect to project constraints, stakeholders and potential new risks.

Figure 35 outlines the relationship between the client brief, project management plan, project procedures (in accordance with the project management plan), project monitoring and controlling, the key delivery stakeholders, the project deliverables with the project execution process. This stage of the project represents the greatest portion of capital expense and risk.

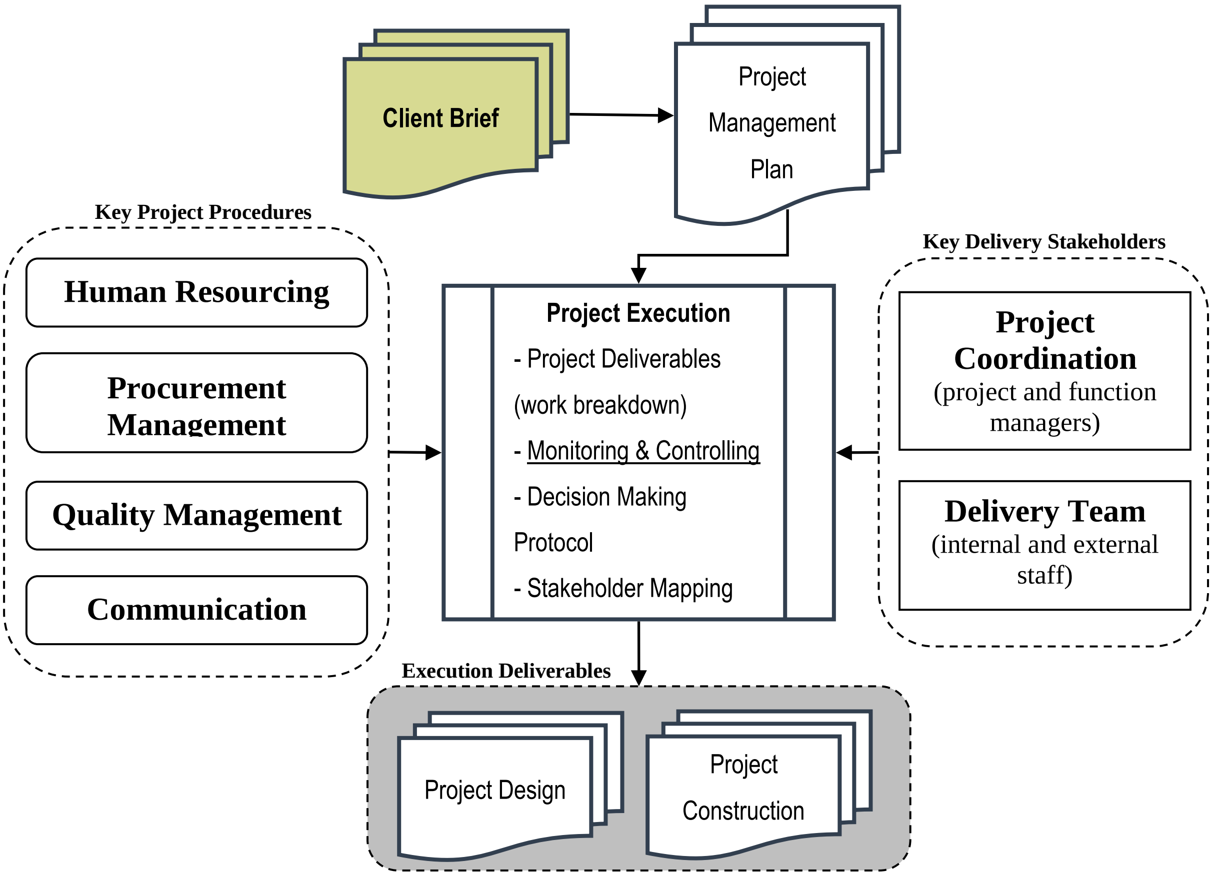

Figure 35: Executing Process - Sustainable Residential Development.

6.4.2.5 Closing Process

The closing process knowledge area consists of the processes to finalise all activities required in the execution and monitoring and controlling of the project. This is the formal recognition that all contractual obligations between the key stakeholders have been satisfied. The content contained within the client brief are represented in the execution deliverables (project design and project construction). The important key to this stage of the project is in project review, documented lessons learnt and apply lessons learnt to ongoing organisational processes and operations development.

Figure 36 outlines the actions required in the 'project closure' process, in relation to the two development outcomes - design and construction. At this point, the operational phase of the development commences. It is good practices for project stakeholders to monitor operation performances with validated predictions during the design and construction of the development.

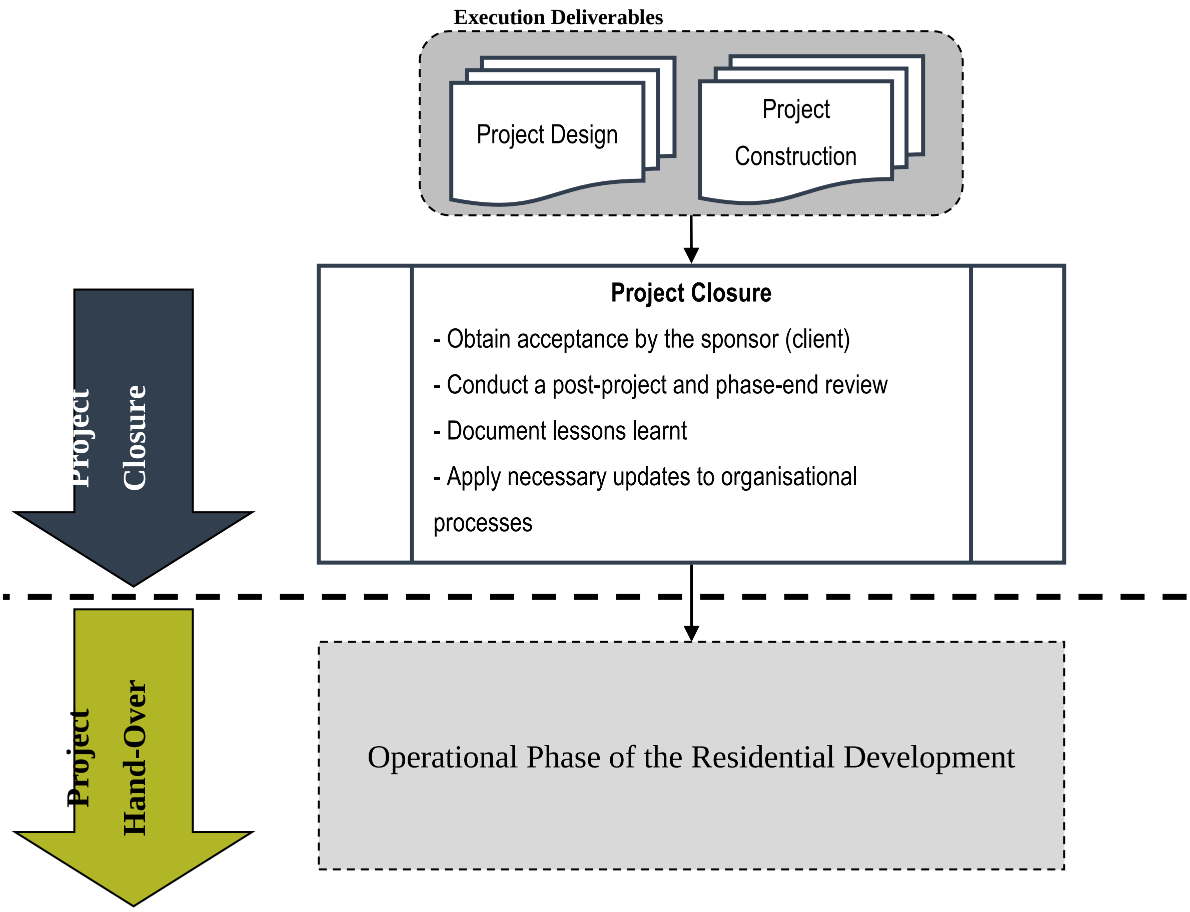

Figure 36: Project Closure Process.

6.4.3 Project Influences on the Project Management Framework

In the case of residential developments, findings in Chapter 2, Chapter 3 and Chapter 5 suggest that there are four main influences that need to be taken into consideration.

6.4.3.1 Organisation Culture and Structure

The structure and culture of design consultants, building contractor and subcontractors, can significantly influence the delivery of project outcomes with respect to their management, monitoring and controlling (including validating), communication methods and standards. Organisation culture styles may have strong influence on a projects ability to meet its objectives. Most organisations have development a unique culture that manifest in numerous ways, including, but not limited to (PMI, 2008):

- Shared vision, values, 'norms', beliefs and expectations
- Policies, methods and procedures
- View of authority relationships, and
- Work ethics and work hours.

6.4.3.2 Stakeholders Influence

Stakeholders have a high level of influences at the early stages of the project (PMI, 2008). As the project progresses, the level of stakeholder influence and risk reduces. As expressed earlier, the residential development industry has two defined milestones/deliverables for building developments - they are: design development, and construction. The management of designer and construction stakeholder influences needs to be specifically managed at the tendering stage of the development (Builder 1, 2014, Builder 2, 2014). This key time in the project (typically) illustrates the validation of construction assumption made in the client brief and design. Builder 1 (2014) illustrates that this period in the construction can cause the greatest conflict between the client, lead designer and builder - re-evaluating project decisions to ensure they match with the initial client brief and the project execution of the construction.

Section 6.3.2 outlines the proposed stakeholder structure to ensure each stakeholder is involved in the delivery of the client brief. The specific influences each key stakeholder has at each key milestone during a residential building development is outside of the scope of this research and framework.

6.4.3.3 Government and Legislation

The approval authorities and approved legislation, guidelines and standards influence the concept and detailed building design. The approval process (Planning Stage) is an unavoidable risk, for either the Development Application or Complying Development stages. Building Designer 1 (2014) expressed "...that most planning documents are written with good intent, but the risk is apparent in the administering and governing the planning documents. Personal agendas by the administering town planner can come into play, which are unavoidable for any project DA submission." In addition, Building Designer 1 (2014)

explains that within the NSW housing code, 'blunt objects' hinder 'general rule' sustainability, i.e. solar access, orientation and passive design. For example, the planning process relies on BASIX to measure a houses level of form and sustainability merits. "Due to [BASIX] innate nature, it will never bring a sustainable solution to the building industry." (Building Designer 1, 2014).

Creating sustainable outcomes needs to be taken from first principles, and validated with founded methods and tools. Through evaluation and validation, a merited conclusion can be presented for collaboration with local government authorities. This is an important influence that cannot be ignored, but considered and managed with respect to the development of the client brief, management plan and risk profile.

6.4.3.4 Awareness of Sustainability

The influence of sustainability awareness on the project outcomes can be significant, and needs to be managed during the development of the client brief and project management plans. A residential client typically does not commission the construction of two houses; therefore their knowledge in sponsoring the residential development project comes with limits. The limits could be no background knowledge in sustainability, building design, compliance, construction and project management. Therefore the education and communication of project direction and decisions relies on the project manager and functional managers to supply concessive information, coupled with educational material to all informed decision-making.

6.5 Chapter Summary

The aim of this research is to develop a project management framework to successfully deliver sustainable residential developments. This chapter outlined the developed framework ProSustain. ProSustain was developed with respect to knowledge gained from the literature review, solar decathlon case studies and applying action research during the application of the unpublished framework on the two research case studies.

CHAPTER 7. SUSTAINABLE RESIDENTIAL DEVELOPMENT CASE STUDIES

The research aim presented in Chapter 1 outlined the development a project management framework for delivering sustainable residential developments (ProSustain). The developed framework was covered in detail in Chapter 6. Therefore, the aim of this chapter is to demonstrate the practical application of the framework in delivering sustainable residential developments. This chapter first provides the background to the selected case studies. The analysis of the case studies against ProSustain is then presented, dividing the analysis into the three key project objectives: social objectives review; financial objectives review; and environmental objectives review. The chapter concludes by identifying limitations, advantages and potential future changes to ProSustain.

7.1 Case Studies

Two residential development case studies were used to test the application of ProSustain. The case study method was adopted to provide a comprehensive review of ProSustain, through the delivery of results against case study objectives. The results from the case studies have been used to raise possible limitations and shortcomings within the framework.

The selection of the two case study projects was important to accurately demonstrate ProSustain. A key consideration, when selecting the case studies, was to ensure that the objectives of the client matched the aim of the ProSustain framework, i.e. to design and construct a sustainable home. Other considerations were:

- The project scope was to be typical of that for an Australian family;
- The project budget are representative of typical family Australian residential design and construction budgets;
- The author could implement ProSustain first-hand; and
- The project timelines matched the research program.

7.1.1 Case Study A – 'Tree House'

Figure 37: Artist Impression - Tree House Concept - North East Aspect.

<u>Overview:</u>

The first case study is entitled 'Tree House', and will be referred to as Case Study A. The Tree House development was located in the foothills of Wollongong's escarpment region. The development scope was to design and construct a new, 4-bedroom, double-garage and dual living room family home on a steep and rocky block of land. The overall concept was for a simple, but contemporary style home, with final details being left to the discretion of the building designer. This development was situated in a relatively new building estate (approximately 15 years old). The estate contained large blocks of land, that were set into the escarpment, each with commanding views of the surrounding escarpment. The rarity and distinctiveness of the blocks established the estate at the higher-end of the property development market, and therefore led the market to develop large designer homes throughout the estate. The client required a house that met their needs, but also suited the current build scale of the estate. Therefore the design space requirements were:

- Double, lock-up garage;
- Four bedrooms;
- Double living rooms;
- Walk-in wardrobe and en-suite bathroom (to the master bedroom).

The floor plans for this development can be found in APPENDIX H: Case Study A - Floor Plans. In addition, it was a requirement of this development to have as little impact as possible on the natural environment with respect to the natural topography of the land, energy efficiency and water usage, while keeping within the clients' financial means. The total initial development budget was $450,000 (AUD) + consultancy fees + land value.

<u>Specific Development Challenges:</u>

Each development has its own specific challenges that need to be addressed, the main challenges for this development were:

- Geotechnical, the site is Class P: Steep sloping block (approximately 20 degrees) with rocky outcrops, risk of slippage and concealed boulders (under surface) - requiring foundations to be engineered from first principles;
- Within bush fire zoning;
- Environmental Zone 4 (E4) - local council development zoning.

<u>Building Details:</u>

The details of the building outlined below represent the 'as-built' design that was constructed. The building details represent the final design and construction result from implementing ProSustain. This information was used in the applied validation methodologies - outlined in Section 4.4.3 (page 72).

a) *Building Areas:*
  - Garage area: 56sqm
  - Internal conditioned area: 229sqm
  - Outside deck area (suspended and tiled): 20sqm
  - Total area (floor): 305sqm
  - Roof catchment area: 310sqm

b) *Financial (all prices are in AUD and include GST):*
  - Design & project management: $21,560 and $19,800 respectively
  - Other (i.e. surveyor, geotechnical, arborist): $5,050
  - Council, Private Certifier & Industry Super Levy: $6,070
    - Lump sum construction costs: $635,108
    - Cost per sqm (construction): $1992/sqm (inc. GST)

c) *Building Materials:*
  - Facade: Weathertex and Colorbond CustomOrb for suspended Level 1, acrylic rendered blockwork for masonry walls (Ground Level).
  - Flooring: Slab on ground to garage, engineered flooring (generally), carpet to bedrooms, tiled floor to other areas.

- Roof: Colorbond TrimDek
- Concrete: N25, 20% recycled content
- Timber: FSC/AFS certified or recycled
- Wall and ceiling lining: Plaster board
- Bulk insulation: 80% recycled content, 100% recyclable
- Rigid insulation: PIR and XPS foam (zero ODP, CFC and HCFC free)
- Paints and adhesives: Low VOC (Green Star compliance levels applied).

d) Windows:

- Aluminium frames
- Argon filled doubled glazed (typical configuration: 4mm glass/12mm argon/4mm glass)
- U value range between 3.0 to 3.9 (dependent on window/door type)
- SHGC range between 0.49 to 0.61 (dependent on window/door type).

e) Technologies:

- 4.94kW LG MonoX Panel with SMA SB5000TL Inverter
- LED Lighting (throughout)
- Solar hot water system (310L stainless steel holding tank & evacuator tubes)
- 22,500 litre water tank
- Rainwater treatment by a four stage process (5 micron washable filter, activated carbon block filter, 1 micron poly-propylene filter, and 95W UV light steriliser).

f) Maintenance/Warranties (product and installation):

• Builders warranty:	7 years
• Paints and sealants:	10 years minimum
• Facade:	25 years minimum
• Roof:	25 years minimum
• Services:	15 years minimum
• Water treatment (maintenance):	12 to 18 months
• Internal fixtures and fittings:	15 years minimum
• Structure:	100 years.

7.1.2 Case Study B - 'Escarpment View'

Figure 38: Artist Impression - Escarpment View - North Aspect.

Overview:

The second case study is entitled 'Escarpment View', and will be referred to as Case Study B. The Escarpment View development was also located in the foothills of Wollongong's escarpment region. The development scope was to design and construct a new, 4-bedroom, single-garage and dual living room family home on a steep and rocky block of land. In addition, the brief also required the design and construction of a detached health consultant room (for massage). The overall concept was for a simple, but traditional-contemporary style home, with a higher level of client involvement in detailing and material selection. One of the objectives for this development was to have as little impact as possible on the natural environment, while keeping within the clients' financial means - the total development budget is $500,000 (AUD) + land value.

Specific Development Challenges:

The main challenges for this development were:

- Site access, narrow very steep block with limited access from the front. The use of cranes will be limited from the street - due to the close proximity of a nearby hospital, ambulance and fire depot;
- Geotechnical, the site is a Class P; extremely reactive clay - foundations need to be engineered from first principles;

- Removal of an existing 1960's house - containing asbestos;
- Health consult room, additional level of compliance and documentation required for DA and CC submission.

Building Information and Statistics:

As with Case Study A, the details of the building outlined below represent the 'as-built' design specifications that were constructed. The building details represent the final design and construction result from implementing ProSustain. This information is used in the applied validation methodologies - outlined in Section 4.4.3 (page 72).

a) *Building Areas:*

• Garage area:	43.7sqm
• Internal conditioned area:	205.2sqm
• Home business area (conditioned):	29.3sqm
• Outside deck area (suspended and tiled):	66.2sqm
• Total area (floor):	364.4sqm (inc. suspended, waterproofed tiled deck area over habitable space)
• Roof catchment area:	203sqm

b) *Financial (all prices are in AUD and include GST):*

• Design & project management:	\$24,200 and \$24,395 respectively
• Other (i.e. surveyor, geotechnical, arborist):	\$4,525
• Council, Private Certifier & Industry Super Levy:	\$8,070
– Lump sum construction costs:	\$643,914
– Cost per sqm (construction):	\$2,054/sqm (inc. GST)

c) *Building Materials:*

- Facade: Weathertex for suspended Level 1, acrylic render to rigid insulation to ground level.
- Flooring: Slab on ground to garage, marmoleum flooring to ground level, engineered flooring to level 1, carpet to bedrooms, tiled floor to other areas.
- Roof: Colorbond TrimDek and CustomOrb
- Concrete: N25, 20% recycled content
- Timber: FSC/AFS certified or recycled

- Wall and ceiling lining: Plaster board (timber lining to kitchen ceiling)
- Bulk insulation: 80% recycled content, 100% recyclable
- Rigid insulation: PIR and XPS foam (zero ODP, CFC and HCFC free)
- Paints and adhesives: Low VOC (Green Star compliance levels applied).

d) Windows:

- Fibre glass exterior and timber interior
- Argon filled doubled glazed (typical configuration: 4mm glass/12mm argon/4mm glass)
- U value range between 1.7 to 2.2 (dependent on window/door type)
- SHGC range between 0.46 to 0.59 (dependent on window/door type).

e) Technologies:

- 3.0kW LG MonoX Panel with SMA SB5000TL Inverter
- LED Lighting (throughout)
- Solar hot water system (310L stainless steel holding tank & evacuator tubes)
- 25,000 litre water tank
- Rainwater treatment by a four stage process (5 micron washable filter, activated carbon block filter, 1 micron poly-propylene filter, and 95W UV light steriliser)

f) Maintenance/Warranties (product and installation):

- Builders warranty: 7 years
- Paints and sealants: 10 years minimum
- Facade: 25 years minimum
- Roof: 25 years minimum
- Services: 15 years minimum
- Water treatment (maintenance): 12 to 18 months
- Internal fixtures and fittings: 15 years minimum
- Structure: 100 years

7.2 Sustainable Project Objectives

Sustainability objectives provided the projects with prescriptive sets of deliverables. ProSustain outlined key sustainable objectives that should be considered when developing the client brief (specific project objectives), and developing the developments project management plan - refer to Table 23 (page 130). For each case study, each objective was considered in the development of the client brief and project management plan.

The following sections evaluate the implementation of ProSustain against the three types of sustainable objectives: Social, Financial and Environmental.

7.2.1 Deriving the Client Brief

The ProSustain framework holds that the Client Brief represents the document that formally authorises the commencement of the project, and documents the objectives of the project. In the presentation of results in this research, each objective type (social, financial and environmental) was evaluated and discussed individually, with this section focussing on the social objectives of each case study.

Developing the client brief is a critical stage in the project life-cycle. However, developing an effective method to derive this key document is outside of the scope of this research, and therefore ProSustain. ProSustain provides guidance on what should be considered when developing this document. In addition, the information collected from the literature review and professional interviews suggested that there was no existing method to guide the successful development of this document. The author therefore adopted key considerations from Building Designer 1 (2014), Architect 1 (2014) and Nervegna (2006).

The present author used two methods to develop the client brief with respect to the sustainability objectives. Firstly, a *pro-forma* or questionnaire was issued to each client to capture the requirements for each dwelling. This *pro-forma* contained questions relating to: room types, number of rooms, building functions, warranties and maintenance, aesthetic considerations and specific personal/client requirements. Secondly, each client was asked to create an online scrapbook of pictures that illustrated the ‘feel’, materials and aesthetics that they were aiming to achieve. This capture of requirements, along with ProSustain's sustainability objectives, led to the creation of the client brief for each case study project.

7.3 Project Social Objectives

As stated previously, the social objectives were developed with respect to the sustainability objectives outlined in ProSustain. ProSustain outlined the following five social objectives, all of which were adopted in each case study:

1) To adhere to ethical trading and fairness-at-work standards policies
2) An increase in yearly thermal comfort
3) To integrate the development within the locality
4) To conserve local culture and heritage, if appropriate
5) To provide housing to meet needs of the client.

Objective 5 reflects the unique objective for each new project, and therefore represents the specific needs of the client. The specific needs for each case study client are as follows:

<u>Case Study A</u>

- 4-bedroom (moderate in size);
- En-suite and walk-in robe for master bedroom;
- Large open kitchen, living and dining room that connected to outdoor space;
- A separated living space for kids (rumpus room);
- Large double garage with storage for extracurricular activities (bikes, surf boards, landscaping tools, etc);
- Building form worked with the natural exposed rock found on site;
- Contemporary style house, with exposed structure;
- Future proofing with respect to aging client and house function; and
- Minimal building maintenance.

<u>Case Study B</u>

- 4-bedrooms (moderate in size);
- Main bedroom to have walk-in robe, personal study and personal outside area;
- Detached space for home office use (remedial massage clinic);
- Large combined space for a single garage space and woodworking (requiring 3 phase power connection);

- Designated area outside for a Japanese spa;
- Combined kitchen and dining space that has northern aspects;
- Separated living space;
- Contemporary style house, with exposed structure;
- Future proofing with respect to aging client and house function; and
- Minimal building maintenance.

7.3.1 Evaluation of Social Objectives

Social objectives are difficult to evaluate because of their qualitative nature. In addition, these objectives typically are particularly difficult to evaluate during the design and construction stages, and therefore are best evaluated upon project completion. Objective 1 was considered and implemented through management processes and contractual requirements. Ethical trade was upheld through project documentation and fair-tendering processes, while the fairness-of-work standard was upheld through the specific contract inclusions and the management of their execution. Project documentation outlined required building performances and specifications (not specific products/systems), thus allowing a wider range of tendering parties to tender with their possible building options. The tendering process required the service and/or work to be tendered to at least three different companies. It also outlined the conditions of tender (i.e. tender timeline, expectations, tender evaluation method and tender selection). The specific contract inclusions to ensure fairness-of-work were: company insurances (level of cover); safety systems and compliance; superannuation payment records; and construction site rules (i.e. language, clothing, smoking, toilets and lunch areas).

Objective 2 was linked directly with environmental thermal performance, and therefore is discussed in Section 7.5.4.

The purpose of Objective 3 was to ensure new developments fit well within the current streetscape and natural environment of the area. This objective represents the main goal of the LEP, DCP and the development application process, and therefore assessed by the local government. For both case studies, they were evaluated against the Wollongong LEP and Wollongong City Council DCP, with neighbour consultation. Both case study developments received DA consent.

Objective 4 was not applicable to the current case studies.

As stated previously, Objective 5 represents the specific requirements of each case study client. This objective was the most difficult to achieve and balance with other project objectives because it is directly related to project cost. After implementing ProSustain, the Author considers the balance between client requirements and the project budget key in managing and delivering the other project objectives. With respect to Case Study A and B, both project budgets were increased by 29.1% and 30.0% respectively. However, both project budgets were increased because of the requirements stated in objective 5. Therefore, the two case study clients considered achieving the requirements more important than the original budgetary increase. Different financial circumstances could have resulted in an increased emphasis on maintaining the budget, which would have seen a notable reduction in the original social requirements. The case study drawings and specifications demonstrate how the needs of client in each case study were considered and adopted into the design (refer to APPENDIX H: Case Study A - Floor Plans and APPENDIX I: Case Study B - Floor Plans. Although, this does not considered how the house functions and operates for each client. The next logical step is to undertake a survey with each client, to evaluate their perceptions on the final house. However, due to research project time constraints and expected completion dates of the case studies, this was not possible.

It is noted noted a key consideration in managing the social aspects of Objective 5 and the overall project budget - the project 'fit-out'. The fit-out of the house refers to the quality of finishes (e.g. floor coverings, wall lining, ceiling lining, stairs and handrails), fixtures (e.g. kitchen, cupboards, vanities, laundry and fixed furniture) and fittings (Electrical: e.g. light fittings, light switches, power points, and ceiling fans. Plumbing: e.g. guttering, down-pipes, basins, taps, toilets, shower heads, and floor wastes). The level of quality was not specified during the development of objective 5. However, in most cases the level of quality required by the clients for the fit-out were beyond the standard ranges in typical Australian 'Project Home' houses. This added an unexpected increase in the project cost after the projects were approved by the local authorities. In most cases, the decisions were made to maintain the higher level of quality. The level of quality in the building fit-off items should be considered at the commencement of the developing the client brief, and specific advice given around the expected increase in project costs.

7.4 Project Financial Objectives: Project Budget

This section outlines the application of ProSustain, with respect to the financial objectives for the case studies. The aim of this section is to validate ProSustain by demonstrating the financial deliverables for each case study, and present the authors commentary for the applicability, adaptability, challenges, and positives of ProSustain. The financial deliverables will be validated by benchmarking the case studies with current industry unit rates. Each case study has been tendered to three builders within the Illawarra region, during the tender process the builders were asked to define and refine their costs with respect to the 'as-built' documentation. A contractor was selected for each case study, and the pricing presented in this research represent the final fixed price for each case study.

7.4.1 Present Author's Perspective

Delivering building development projects on budget can be a difficult task, especially when the main focus is placed on the clients social requirements of the house (i.e. rooms, building form and materials - Objective 5), and not focused towards developing a building design that works within the budget. Each case study client specified an initial budget, capable of building a house. However, their specific building requirements and fit-out quality led each case study project budget to increase. In addition, environmental considerations also added to the budget and decision making process. Balancing the social and environmental objectives of each case study against their respective budgets was a challenge, but critical in ensuring each objective type was considered, balanced and achieved. The budget became the reference point for client decision making. This allowed the client to take ownership of the budget, with respect to their decisions.

As outlined in ProSustain, defining an adequate project budget and developing and implementing a plan to manage the budget it critical. For the two case studies, the author separated the project cost into two areas: 'Consultancy, Compliance & Levies' and 'Construction'. To ensure accountability of project expenditure towards achieving project objectives, the author further separated the two project sub-budgets.

1. <u>Consultancy, Compliance and Levies</u>

- Consultancy:
    - Building Designer / Architect
    - Surveyor
    - Structural Engineer
    - Geotechnical Engineer
    - Stormwater Engineer (if required)
    - Horticulturalist (if required)
- Compliance
    - DA Application Fee (local government)
    - CC Application Fee (local government or private certifier)
    - BASIX Fee
    - Sydney Water
- Levies
    - Long Service Levy
    - Section 94a

2. <u>Construction</u>

- Builders Preliminaries
    - Warranties and Insurances
    - Site Preliminaries (environmental control, temporary fencing, site office, site toilet, cranes, scaffold, etc...)
    - Builder’s Profit Margins
    - Builder’s Contingency
- Structure
    - Demolition (if required)
    - Civil Works (excavation and services connection to mains)
    - Concrete Works
    - Structural Steel (if applicable)
    - Blockwork (if applicable)
    - Structural Timber (including battens)

- Services
    - Mechanical
    - Hydraulic (Plumbing. Include PC items)
    - Electrical (Include PC items)
- Facade
    - Building Facade (Including membrane and insulation)
    - Roof
    - Windows
    - Exterior Painting
    - Miscellaneous (garage doors, balustrades, etc...)
- Interior Fit-out
    - Interior Lining (floor, wall and ceiling)
    - Fixtures (kitchen, laundry, cupboards, etc...)
    - Internal Painting
    - Stairs
- Exterior Works
    - Landscaping
    - Fencing
    - Miscellaneous (clothes lines).

Once the building concepts were completed for both case studies, the author developed a project budget based on the above project break-down. At this point, it was clear to the author that both designed concepts did not meet their initial project budget, but met their social and environmental objectives. The inclusion of the decision making protocol into ProSustain (refer to 6.3.3 Decision-making Protocol - page 134) was a result of the process of refining the initial concept to better met their financial objective while consideration and maintaining their social and environmental objectives. The project budget breakdown allowed decisions to have a common evaluation metric, i.e. cost. Therefore all decisions associated to the project's social and environmental requirements were referred back to the overall project cost (a recommendation by Builder 1 (2014)). In addition, project decisions were also coupled with the required information. The author feels that this approach gave the client more control over how their social and environmental decisions impacted the budget with respect to the possible outcomes - the balance of the projects objectives.

To validate project construction cost during the design development and tendering process, the author compared budget estimates with industry unit rates.

7.4.1.1 Industry Rates - Cost Benchmark

Determining a specific industry unit rate for the construction costs of sustainable houses is difficult, and in some instances lend themselves to 'Cost Plus' contracts (Builder 1, 2014, Builder 2, 2014, Architect 1, 2014). Professor Deo Prasad (2010) claimed that sustainable results should be achievable with minimal increases in initial construction expenditure of between 2 to 5%.

There are several commercially available tools to assist in the development of construction costs, with associated level of fit-out quality. An open-source, unit rate prices new residential construction (including typical extension) costs between $1,900 to $3,400/sqm plus GST (Ask An Architect, 2014). Rawlinsons (2015) provides more specific ranges with respect to construction type and quality levels. The quality ranges are: Medium, High and Prestige. For reference, the two case studies were referenced to a framed house construction with a medium to high level of internal fit-out in the Sydney area. The rates proposed by Rawlinsons (2015) were:

- Individual House (framed construction, medium standard): \$1,716/m^2 (inc. GST)
- Individual House (framed construction, high standard): \$2,370/m^2 (inc. GST).

The above rates were used to compare the overall unit costs for each case study. Note, the illustrated prices for the two case studies were the result of a tender period between September to November 2014, inflation factors were not applied to the above benchmark rates.

7.4.2 Tree House - Case Study A

The final, fixed price cost of the construction of this case study was $635,108 including GST. From the initial budget set by the client (of $450,000 including GST), this represented an increase of 29.1%. The above construction cost did not include professional fees, local

government charges or levies. For Case Study A, this totalled $52,480 (including GST). Table 24 outlines the construction breakdown for this case study.

Table 24: Fixed Price: Cost Breakdown for Case Study A

Trade Package	Budget ($)	% of Total Cost	Description
Preliminaries			
Pre Site Costs	$6,000	0.94%	Warranties & insurances
Site Preliminaries	$15,000	2.36%	Environmental controls, temporary fencing, site office, site toilet, cranes, scaffold, etc...
Builders Margin	$45,893	7.23%	10% of contracted items
Contingency	$15,000	2.36	
Structure			
Demolition	$0	0.00%	Not applicable
Civil Works	$21,305	3.35%	Excavation
Concrete Works	$19,576	3.08%	Formwork, reinforcement, concrete
Structural Steel	$27,000	4.25%	Fabricate, protect and erect
Block Work	$16,500	2.60%	Core filled block work
Structural Timber	$52,000	8.19%	Level 1, walls, roof (inc. battening & flooring underlay)
Services			
Mechanical	$0	0.00%	Not applicable
Hydraulic	$39,000	6.14%	Inc. medium to high-end PC items
Water Tank, Treatment Unit & Pump	$6,500	1.02%	22,500L rainwater tank, 100L/s flow rate treatment and pump unit, 4 stage treatment unit
Electrical & Level 2	$28,900	4.55%	Inc. medium to high-end PC items (all LED light fittings)
PV System (5kW)	$8,640	1.36%	Supply and installed
Facade			
Exterior Cladding	$55,057	8.67%	Inc. 2.5R Knauf HD insulation, membrane. Facade is a combination of WeatherTex & ColorBond
Roof	$19,000	2.99%	Inc. roof sheeting, flashing, 1.5R Knauf reflective roll, gutters & downpipes and installation.
Windows	$32,000	5.04%	Rylock A-A Series double-glazed windows (inc. installation)
Painting	$9,000	1.42%	External only

Garage Door	$5,000	0.79%	Supply and install
Recycled Hardwood Beam & Posts	$3,500	0.55%	
Balustrade	$9,000	1.42%	Surrounding outside deck area
Interior Fit Out			
Kitchen	$18,000	2.83%	
Kitchen Appliances	$8,000	1.26%	All new appliances
Internal Lining	$31,000	4.88%	Inc. insulated plaster board. Note, square set cornice throughout
Painting	$12,000	1.89%	Internal Only
Laundry	$2,000	0.31%	Supply and install
Floor Coverings	$37,000	5.83%	Inc. wet areas - water proofing, grout beds, tiling (inc. walls). $130/sqm allowance for general areas & $50/sqm allowance for carpet
Internal Stairs	$8,500	1.34%	Supply and install
Fix Out	$9,000	1.42%	All misc. timber works, inc. doors, bathroom PC furniture items
Misc. Cabinetry	$3,000	0.47%	Vanity, glass shower screens, etc.
Exterior Works			
Driveway	$15,000	2.36%	110sqm of driveway

Sub Total	$577,331		
GST	$57,737.10		10%
Grand Total	$635,108.10		Fixed Price Build Contract

Initial Construction Budget	$450,000		Initially defined budget
Variation	29.1%		Final variation from initial budget
Cost/sqm	$1,992.69		306 sqm

To accurately compare the final construction cost against Rawlinsons (2015) unit rates, the final construction cost needs to be adjusted to align with the specified inclusions and exclusions. The adjusted construction cost is $609,764.10, which is a unit rate for this case study of $1,992.69 per square meter (including GST). The construction unit rate for this case study is positioned between the medium to high standard unit rates offered by Rawlinsons (2015).

This method of cost planning also allows for analysing the additional cost of environmental features during the concept design, detailed design and tendering processes. The 'As-Built' design (cost breakdown listed above) has an increased construction cost then the corresponding Building Code of Australia (BCA) compliant design. As noted, this method allowed the designer to quantify the added cost for each environmental feature. The as-built design performance of Case Study A required a 5.2% increase in upfront construction cost. This equates to $33,160 including GST (AUD). Table 25 outlines the key environmental features, and their associated costs with respect to the corresponding BCA complaint design.

Table 25: Change in Project Cost with Environmental Features - Case Study A

Incorporated Feature	BCA Compliant Cost	As-Built Cost	Variation (%)
PV System	$0.00	$8,990.00	100%
Water Collection	$0.00	$3,490.00	100%
Water Treatment/Pump	$0.00	$2,790.00	100%
Rigid Insulation	$0.00	$4,290.00	100%
Windows	$21,990.00	32,990.00	33%
LED Lighting	$2,990.00	$2,990.00	0%
Solar Hot Water	$1,890.00	$4,490.00	71%
Total	**$26,870.00**	**$60,030.00**	**55%**
Total Project Cost	**$601,948.10**	**$635,108.10**	**5.2% ^**

7.4.3 Escarpment View Case Study B

The final, fixed price cost of the construction of this case study is $649,919.60. From the initial budget set by the client (of $500,000 - including GST), this is an increase of 30.0%. The above construction cost does not include professional fees, local government charges or levies. For Case Study B, this totalled $61,190 (including GST). The cost breakdown listed in Table 26 represents the final negotiated cost with the appointed building contractor.

Table 26: Fixed Price: Cost Breakdown - Case Study B

Trade Package	Budget ($)	% of Total Cost	Description
Preliminaries			
Pre Site Costs	$9,450	1.60%	Warranties & insurances
Site Preliminaries	$9,780	1.66%	Environmental controls, temporary fencing, cranes, site office, site toilet, scaffold, etc...

Builders Margin	$50,361	8.52%	10% of contracted items
Contingency	$10,000	1.69%	2% of build cost (pre GST)
Structure			
Demolition	$6,300	1.07%	Brick & concrete waste
Civil Works	$8,230	1.39%	Excavation (bulk & detailed)
Concrete Works	$51,525	8.72%	Formwork, reinforcement, concrete
Structural Steel	$0	0.00%	Not applicable
Block Work	$11,280	1.91%	Supplied and laid
Structural Timber	$54,964	9.30%	Walls, suspended level 1, roof (inc. battening & flooring underlay)
Services			
Mechanical	$0	0.00%	Not applicable
Hydraulic	$27,900	4.72%	Inc. medium to high-end PC items
Water Tank, Treatment Unit & Pump	$7,450	1.26%	25,000L rainwater tank, 100L/s flow rate treatment and pump unit, 4 stage treatment unit
Electrical & Level 2	$19,180	3.25%	Inc. medium to high-end PC items (all LED light fittings)
PV System (3kW)	$5,890	1.00%	Supply and installed
Facade			
Exterior Cladding	$92,408	15.64%	Inc. 2.5R Knauf HD insulation, membrane. Facade is a combination of WeatherTex & Rendered Rigid Insulation
Roof	$23,998	4.06%	Inc. roof sheeting, flashing, 1.5R Knauf reflective roll, gutters & downpipes and installation.
Windows	$37,860	6.41%	Fibreglass exterior and timber interior frames. Double glazed.
Painting	$4,725	0.80%	External only
Garage Door	$2,750	0.47%	Supply and install
Render	$0	0.00%	Included
Balustrade	$14,500	2.19%	Surrounding outside deck area
Interior Fit Out			
Kitchen	$15,000	2.54%	
Kitchen Appliances	$8,000	1.35%	All new appliances
Internal Lining	$35,660	6.04%	Inc. insulated plaster board. Note, square set cornice throughout
Timber Lining	$1,380	0.23%	Inc. hardwood feature bulkhead
Painting	$10,500	1.78%	Internal Only

Laundry	$2,000	0.34%	Supply and install
Floor Coverings	$31,625	5.35%	Inc. wet areas - water proofing, grout beds, tiling (inc. walls). $100/sqm allowance for general areas & $50/sqm allowance for carpet
Internal Stairs	$6,500	1.10%	Supply and install
Fix Out	$5,270	0.89%	All misc. timber works, inc. doors, bathroom PC furniture items
Misc. Cabinetry	$0	0.00%	Included
Exterior Works			
Driveway	$14,000	2.37%	110sqm of driveway
Outdoor Terrace	$12,350	2.09%	Waterproofing membrane, grout bed and tiling

Sub Total	$590,836.00		
GST	$59, 083.60		10%
Grand Total	$649,919.60		Fixed Price Build Contract

Initial Construction Budget	$500,000		
Variation	30.0%		Final variation from initial budget
Cost/sqm	$2,054.14		298sqm

As shown in Case Study A, to accurately compare the final construction cost against Rawlinsons (2015) unit rates, the final construction cost needed to be adjusted to align with the specified inclusions and exclusions. The adjusted construction cost was $612,134, which was a unit rate for this case study of $2,054 per square metre (including GST). The construction unit rate for this case study was positioned between the medium to high standard unit rates offered by Rawlinsons (2015).

This method of cost planning also allows for analysing the additional cost of environmental features during the concept design, detailed design and tendering processes. The 'As-Built' design (cost breakdown listed above) had a higher construction cost than the corresponding Building Code of Australia (BCA) compliant design. As noted, this method allowed the designer to quantify the added cost for each environmental feature. The as-built design performance of Case Study B required a 7.3% increase in upfront construction cost. This

equates to $47,295 including GST (AUD). Table 27 outlines the key environmental features, and their associated costs with respect to the corresponding BCA complaint design.

Table 27: Change in Project Cost with Environmental Features - Case Study B

Incorporated Feature	BCA Compliant Cost	As-Built Cost	Variation (%)
PV System	$0.00	$6,479.00	100%
Water Collection	$0.00	$3,490.00	100%
Water Treatment/Pump	$0.00	$2,790.00	100%
Added Insulation	$0.00	$5,280.00	100%
Windows	$14,990.00	$41,646.00	64.0%
LED Lighting	$2,990.00	$2,990.00	0%
Solar Hot Water	$1,890.00	$4,490.00	57.9%
Total	**$19,870.00**	**$67,165.00**	**70.4%**
Total Project Cost	**$602,624.60**	**$649,919.60**	**7.3% ^**

7.5 Project Environmental Objectives: Environmental Outcomes

This section outlines the application of ProSustain, with respect to the environmental objectives for the case studies. The aim of this section is to validate ProSustain by demonstrating the environmental deliverables for each case study, and to present the researcher's commentary on the applicability, adaptability, challenges, and positives of the framework. The environmental deliverables were validated by benchmarking the case studies against the equivalent BCA compliant design. The case studies were benchmarked on: water use/water analysis; cradle to grave embodied energy; life-cycle analysis; and thermal comfort/energy demands and energy modelling.

7.5.1 Researcher's Perspective

Designing, cost planning, approval process and contracting builders for each project proposed the same set of challenges. The initial design for both projects commenced with designing homes that met all of the clients' social requirements, and an expected construction budget was developed to reflect the concept design. At this time, specifying the most appropriate materials, details and systems, and then determining associated costs was fairly straightforward. However, validating the results and comparing against the BCA compliant design (the benchmark) proved to be time-consuming, and in most cases had another

associated cost. Through benchmarking the as-built design, and considering the environmental impacts of materials through their selection process, measurable results for each environmental objective was achieved.

The three environmental objectives outlined in ProSustain are:

1) To minimise the use of resources
2) To minimise pollution
3) Reduce operational demand (energy, water, waste water, gas)

The author determined the operational environmental outcomes of each case study by conducting an energy model (using DesignBuilder software to the NatHERS protocol) and a water analysis (derived from first principles). A life-cycle analysis (using an online software named eTools) was conducted to measure the overall reduction in material, construction, operation, maintenance and dismantle resources. The method to select materials was also important to ensure the minimisation of pollution, however this was difficult to prove any minimisation. When selecting materials, the author considered the overall performances (which included: aesthetics, structural integrity, durability, warranties, maintenance, work-ability and detailing) of the material (and/or system), against material cost and the materials manufacturing processes and the fabric of the material (what the material contains). In addition, the availability of products and their compliance with Australian Standards and other materials was considered. An effective method, tool or protocol for selecting building materials is outside of the scope of ProSustain, however an area that the author feels is important and warrants further investigation.

A key consideration during the development of ProSustain was its ease of understanding, application and adaptability. Guiding individuals and businesses to start, manage and deliver sustainable housing outcomes. Conducting the validation methods used by the author was time consuming, and for an individual or business that does not specialise in building design (and detailing), thermal performance, energy modelling, hydrology, mechanical systems, and/or conducting life-cycle analysis may need to outsource some or all of the above validation methods. This could be considered an early flaw in the greater adoption of the framework, or a needed area of up-skilling in the current residential consultancy industry. The time consuming aspect in validating the performances was in developing efficient methods to managing the design process with the validation tools - not conducting the

validation themselves. Developing effective methods to managing the integrations of the environmental validation tools into the design process will increase the efficiency in developing, but also value add to the available information during decision making.

Developing a tailored method for managing the integration of environmental validation should also help alleviate the noted challenge in sustainability awareness and understanding. For the client, the challenge arose with the specifying of specified materials, details and technical systems because they generally had an associated additional cost. Each case study client was already aware of sustainability within houses, but they relied on the information given by the building designer to validate their inclusion. This created a challenge in the delivery of the social, financial and environmental objectives during the design stage, because designing (whilst considering the construction methodologies) is a highly iterative process. Which created a lag effective when providing analysis results in a holistically context.

The building form, character and function must also play a key role in the overall aesthetics, function and social requirements of the project (and not governed by performance optimisation). The approach by the author was to design a home, that firstly met their social requirements (building aesthetics, form and function), and secondly linked this to the projects budget and environmental possibilities. This allowed the features to complement a home, and add-value to the design process, and not drive the overall design and budget. Validating the environmental features commenced with comparing available products and/or system performances with the building design and project budget. The most appropriate product/system was then selected. Finally, the overall project/design was evaluated using analysis methods, and benchmarked against standard BCA requirements. The environmental features were targeted at the beginning of the projects, they were: higher level of insulation - including windows (at a nominal cost increase, and low impact to traditional construction methods), rainwater capture and treatment, PV system (size depended on budget), solar hot water, and energy efficiency. With respect to each project concept and the associated project budget, the highest level of performance for each sustainable feature was targeted.

The second education challenge was with the tendering builders (and appointed contractors). Each builder wanted to revert each design to their common practice, which was generally their preferred products, detail and systems. Educating the builders was considered more difficult by the project manager than the clients', as the builders are professionals in their own

field. Changing their common practice, to new materials, details and construction methods was difficult, especially with respect to their pricing. Each builder considered each 'new' practice as a risk, and therefore tailored their price accordingly. This was overcome in several ways, firstly by presenting projects where similar (or the same) materials, systems and/or details were used. In some cases, specialised sub-contractors and suppliers were put in contact with the tendering builders to help create a sense of confidence. Secondly, samples, technical data sheets, installation guides and warranties were presented to each tendering builder for each new product/system. Finally, by being involved in the construction of the case study houses, a sense of a higher achievement was instilled in the construction team. This seemed to be a powerful motivator for each tendering builder to learn and understand the specified products and systems, as they could be a part a of the journey to develop, validate, and deliver sustainable home.

The method of adapting environmental features, with reference to the cost plan, to the concept design seemed to be a valued method when balancing the social requirements of the building to the overall project budget, with overall environmental performances. Initially, balancing the forecasted cost plan with received tender quotation was difficult a process because tenders were submitted that do not include anything outside of their normal business practices. However the author feels that with ongoing projects and relationship building with local builders will, over time, create a stream-lined tendering and construction process.

7.5.2 Water Use - Water Analysis

The water analysis was conducted to determine the water use, water supplies and water storage for each case study. The results were calculated by determining expected yearly rainfall, captured rainfall (available for the development), water usage (considering specified hydraulic PC item efficiencies - i.e. flow rates/star ratings), and the water storage capacity.

Note, for both case studies, grey and black water were not treated on site (and therefore not allowed for in the case study costing). It was determined at an early stage of the design process that treating grey and black water would add approximately $10,000 to each project. Therefore, for both projects, the decision was made to enlarge the rainwater tank and 'whole-of-house' rainwater treatment units were investigated. Grey and black water treatment could be considered, and plumbed in at a later stage. For both case studies, rainwater fed the entire

home, and is treated via a 4 stage system: 5 micron filter, carbon block, 1 micron filter, and UV light.

7.5.2.1 Rainfall

The water supply for both case studies were calculated using rainfall data collected at the University of Wollongong, and obtained through the Bureau of Meteorology (2014). The rainfall values represented in Table 28 are the monthly mean rain data collected between years 1970 to 2008.

Site Information (Bureau of Meteorology, 2014)

- Site name: WOLLONGONG UNIVERSITY
- Site number: 068188
- Latitude: 34.40 °S
- Longitude: 150.88 °E
- Elevation: 25 m
- Commenced: 1970 Status: Closed 06 Jun 2008
- Latest available data: 05 Jun 2008

Table 28: Wollongong Mean Rain Fall (Bureau of Meteorology, 2014)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Rainfall (mm)	130.3	156.4	160.4	129.3	106.4	112.4	63.4	83.3	67.4	100.5	115.6	94.6
TOTAL	**1320mm**											

7.5.2.2 Assumptions

To conduct the water analysis for both case studies, assumptions were made in regards to occupancy behaviour. The behaviour of the occupants can greatly affect the water demands of the house, but for analysis purposes Table 29 outlines the water analysis assumptions.

Table 29: Occupancy Behaviour - Water Demand

Household

Appliance/Use	Unit	Unit Rate
Dishwater	1	use/day
Washing Machine	3	use/week
Kitchen Tap	20	minutes/day
Laundry Tap	20	minutes/week
Outdoor Tap	10	minutes/week
Bath	1	use/fortnight

Persons

Appliance/Use	Unit	Unit Rate
Shower	10	minutes/day
Toilet	3	use/day
Basin	10	minutes/day

In addition, there were several annual assumptions that needed to be inputted into the calculations:

- At the beginning of each year (1st January), the rain water tank is assumed to be half full.
- The rain water collected each month, is evenly distributed over each day of the month.
- 'First Flush' systems are not included in the calculations.

7.5.2.3 Tree House - Case Study A

The aim of this section is to determine the water balance for this development - Case Study A. The results issued herein represent the yearly demand of water use - from both rainwater and town water, captured rainwater and stored water by this development. With the following results we can predict and minimise the developments demand on town water. This is completed by appropriately sizing the developments rain water tank.

Note: All referenced products and specifications documented within were constructed into the development, and accounted for with the cost breakdown held in Section 7.4.2. The following information was used, specific to this case study:

- Number of Occupants
  - Adults: 2
  - Children: 2

- PC Items (water rating)
  - Showers (min.): 3 Star
  - Toilets (min.): 4 Star
  - Kitchen Tap (min.): 4 Star
  - General Taps (min.): 5 Star
  - Bath: 350 Litres
- Rain Water Tank
  - Tank Size: 22,500 Litres
  - Tank Material: Colorbond
  - Tank Lining: Bladder
  - Tank Colour: Woodland Grey

The water supply for this case study was calculated by using the 'true' area of the roof (the 'Normal' projected area), in conjunction with and the Wollongong rainfall data. The projected area for this case study is **278m^2**. During a calendar year period, this development is expected to collect a total of 367kL, with most of the rainfall collected between January, February and March. Table 30 and Figure 39 illustrates the expected available rainwater for collection each month, for this case study.

Table 30: Estimated Available Rainwater for Case Study A

Month	January	February	March	April	May	June	July	August	September	October	November	December
Est. Available Rainwater (kL)	36.20	43.45	44.56	35.92	29.56	31.23	17.61	23.14	18.72	27.92	32.12	26.28
TOTAL	**366.71kL**											

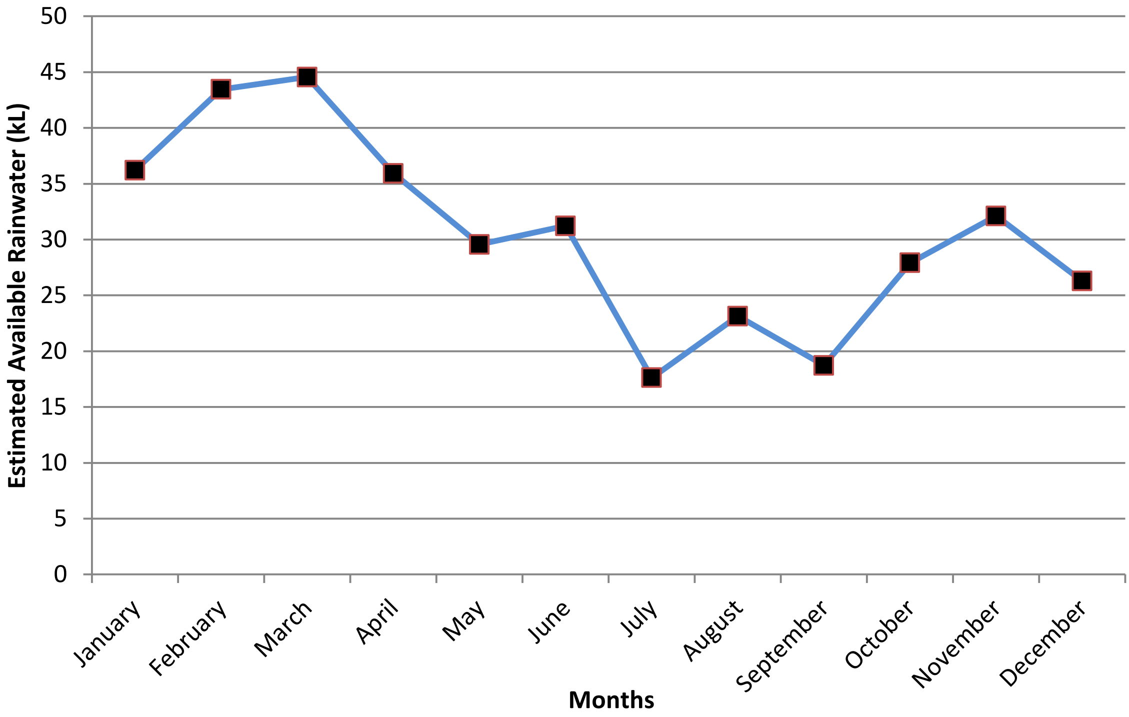

Figure 39: Estimated Available Rainwater - Case Study A.

The water demand analysis for case study A was conducted with reference to the previously outline assumptions, and compared with city-wide water demand values. The Sydney Water (2013) Water Efficiency report estimates the average water use, per capita use within a household (regardless of household size -number of people, and type - e.g. duplex, single dwelling, apartment block) to be 310litres per day, with an estimated per capita use of 286litres per day in 2015. Troy et al. (2005) surveyed 2200 households, and were able to further refine the water use for each location and type of house. With 2001 consensus data, Troy et al. (2005) estimated that an individual living within a 4-bedroom home uses approximately 285litres per day and 405kL per year.

Table 31 represents the predicted water consumption for this development over one calendar year. The total usage for the household is **355.1kL** per year (50kL less than 2001 usage), with an average person daily usage of **243litres**. The predicted usage per capita is approximately 15% less than current average usage. This reduction could be attributed to the efficiency of the hydraulic PC items. For the purpose of this research, the estimated usage per day and per year is considered acceptable.

Table 31: Water Demand Results- Case Study A

Household

Appliance/Use		
Dishwater	5,475	Litres
Washing Machine	5,460	Litres
Kitchen Tap	54,750	Litres
Laundry Tap	6,240	Litres
Outdoor Tap	20,800	Litres
Bath	9,100	Litres

Persons

Appliance/Use		
Shower	146,000	Litres
Toilet	19,710	Litres
Basin	87,600	Litres

Household Per Year	**355,135**	Litres
Household Per Day	**973**	Litres
Per Person Per Day	**243**	Litres

The available roof area, from the house design, allows for an estimated total available rainwater of 366.71kL per year, with an expected use of 355.1kL per year. With the current size of rainwater tank, Table 32 and Figure 40 demonstrates the water analysis results for this development. It is expected that this development will discharge a total of 33.0kL to storm water between February to April, and for the month of June. In addition, it is expected that the development will operate on **97.1%** treated rainwater (344.8kL), and only 2.9% town water (10.3kL) - which will be required during September, October and December.

Note: The uncertain nature of rainfall makes it difficult to predict rainfall supply into the system (rainwater tank) at a more finite level - i.e. day-by-day, then Monthly (as represented below). Therefore, low 'Average Tank Levels' could result in the use of 'Town Water' during these months.

Table 32: Water Analysis Results - Case Study A

Date	Average Tank Level	Average Water Demand	Average Rain Fall	Discharge to Storm Water	Town Water
JANUARY	14171.1	30162.2	36199.0	0.0	0.0
FEBRUARY	21568.4	27243.2	43449.9	10418.6	0.0
MARCH	22500.0	30162.2	44561.1	14399.0	0.0
APRIL	22500.0	29189.2	35921.2	6732.0	0.0
MAY	22208.3	30162.2	29559.3	0.0	0.0
JUNE	22400.6	29189.2	31226.1	1425.9	0.0
JULY	16428.0	30162.2	17613.3	0.0	0.0
AUGUST	6554.2	30162.2	23141.8	0.0	0.0
SEPTEMBER	460.7	29189.2	18724.6	0.0	7325.2
OCTOBER	0.0	30162.2	27920.2	0.0	2242.0
NOVEMBER	1414.2	29189.2	32115.1	0.0	0.0
DECEMBER	1150.61	30162.15	26281.1	0.0	876.4

Total Yearly Water Demand (by development):	**355135**	L
Total Yearly Captured Rainfall:	**366713**	L
Total Yearly Rainfall Discharged to Storm Water:	**32975**	L
Total Yearly Town Water Used:	**10346**	L
Total Yearly Rain Water Used:	**344789**	L
Percentage of Rain Water Discharged to Storm Water:	**9.9**	%
Percentage of Rain Water Used (by development):	**97.1**	%
Percentage of Town Used (by development):	**2.9**	%

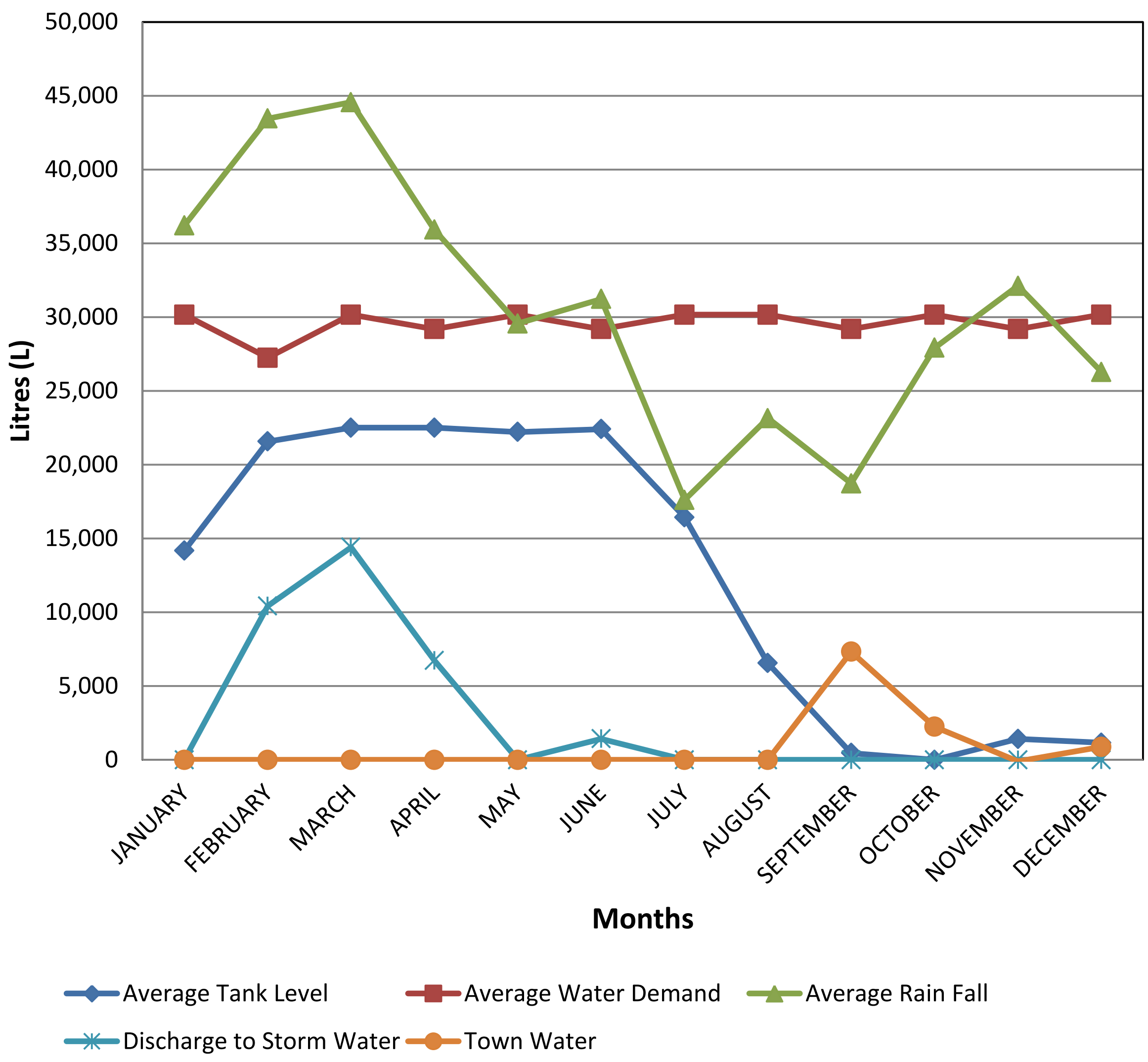

Figure 40: Water Analysis Results - Case Study A.

The following results indicate that a 22,500L rain water tank is sufficient in supporting a high percentage of the development's water needs over a 12-month period. To be confident that no town water is required during the months of September, October and December, it was recommended that the rain water tank size be increased. A 30,000L rain water tank would keep the average tank level above 7,000L in the month of October, and reduce rainwater discharge between the months of February to April. This as-built system reduces the demand on town-water by 344,789 L.

An upgrade in rainwater tank size was expected to cost between $1,000 to $1,500 (AUD). The total as-built system (rainwater tank, treatment unit and water pump) for this case study cost approximately $7,500 including GST (AUS) installed.

7.5.2.4 Escarpment View Case Study B

The aim of this section is to determine the water balance for this development - Case Study B. The results issued herein represent the yearly demand of water use, from both rainwater and town water, captured rainwater and stored water by this development. With the following results it was possible to predict and minimise the development's demand on town water. This was completed by appropriately sizing the development's rain water tank.

Note: All referenced products and specifications documented within were constructed into the development, and accounted for with the cost breakdown held in Section 7.4.2. The following information was used, specific to this case study:

- Number of Occupants
  - Adults: 2
  - Children: 2
- PC Items (water rating)
  - Showers (min.): 3 Star
  - Toilets (min.): 4 Star
  - Kitchen Tap (min.): 4 Star
  - General Taps (min.): 5 Star
- Rain Water Tank
  - Tank Size: 25,000 Litres
  - Tank Material: ColorBond
  - Tank Lining: Bladder
  - Tank Colour: Woodland Grey

The water supply for this case studies was calculated by using the 'true' area of the roof (the 'Normal' projected area), in conjunction with and the Wollongong rainfall data. The projected area for this case study is 203m^2. During a calendar year period, this development is expected to collect a total of 268.36kL, with most of the rainfall collected between January, February and March. Table 33 and Figure 41 illustrates the expected available rainwater for collection each month, for this case study.

Table 33: Estimated Available Rainwater for Case Study B.

Month	January	February	March	April	May	June	July	August	September	October	November	December
Est. Available Rainwater (kL)	26.49	31.80	32.61	26.29	21.63	22.85	12.89	16.93	13.70	20.43	23.50	19.23
TOTAL	**268.36kL**											

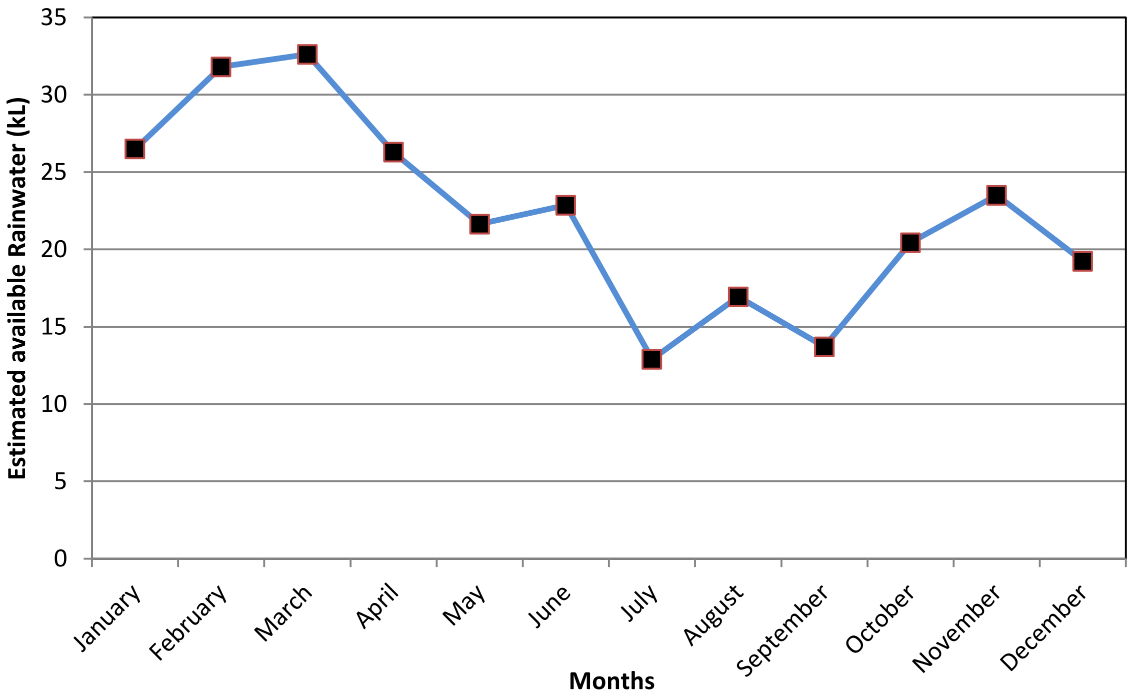

Figure 41: Estimated Available Rainwater - Case Study B.

Table 34 represents the predicted water consumption for this development over one calendar year. The total usage for the household is 346.0kL per year (60kL less than 2001 usage), with an average person daily usage of 237litres. The predicted usage per capita was approximately 17% less than current average usage. This reduction could be attributed to the efficiency of the hydraulic PC items. For the purpose of this research, the estimated usage per day and per year was considered acceptable.

Table 34: Water Demand Results - Case Study B

Household

Appliance/Use		
Dishwater	5,475	Liters
Washing Machine	5,460	Liters
Kitchen Tap	54,750	Liters
Laundry Tap	6,240	Liters
Outdoor Tap	20,800	Liters

Persons

Appliance/Use		
Shower	146,000	Liters
Toilet	19,710	Liters
Basin	87,600	Liters

Household Per Year	**346,035**	Litres
Household Per Day	**948**	Litres
Per Person Per Day	**237**	Litres

The available roof area, from the house design, allows for an estimated total available rainwater of 268kL per year, with an expected use of 346kL per year. With the current size of rainwater tank, Table 35 and Figure 42 demonstrates the water analysis results for this development. It is expected that this development will not discharge any storm water during the year. In addition, it is expected that the development will operate on 81.3% treated rainwater (281.4kL), and 18.7% on town water (64.7kL) - which will be required between June and December.

Note: The uncertain nature of rainfall makes it difficult to predict rainfall supply into the system (rainwater tank) at a more finite level - i.e. day-by-day, then monthly (as represented below). Therefore, low 'Average Tank Levels' could result in the use of 'Town Water' during these months.

Table 35: Water Analysis Results - Case Study B

Date	Average Tank Level	Average Water Demand	Average Rain Fall	Discharge to Storm Water	Town Water
JANUARY	11097.1	29389.3	26490.0	0.0	0.0
FEBRUARY	12132.4	26545.2	31796.1	0.0	0.0
MARCH	16409.8	29389.3	32609.3	0.0	0.0
APRIL	17030.4	28441.2	26286.7	0.0	0.0
MAY	12163.3	29389.3	21631.1	0.0	0.0
JUNE	5457.1	28441.2	22850.9	0.0	0.0
JULY	242.6	29389.3	12889.2	0.0	13838.8
AUGUST	0.0	29389.3	16934.9	0.0	12052.6
SEPTEMBER	0.0	28441.2	13702.4	0.0	14738.8
OCTOBER	0.0	29389.3	20431.7	0.0	8957.6
NOVEMBER	0.0	28441.2	23501.5	0.0	4939.7
DECEMBER	0.00	29389.27	19232.2	0.0	10157.1

Total Yearly Water Demand (by development):	**346035**	L
Total Yearly Captured Rainfall:	**268356**	L
Total Yearly Rainfall Discharged to Storm Water:	**0**	L
Total Yearly Town Water Used:	**64685**	L
Total Yearly Rain Water Used:	**281350**	L
Percentage of Rain Water Discharged to Storm Water:	**0.0**	%
Percentage of Rain Water Used (by development):	**81.3**	%
Percentage of Town Used (by development):	**18.7**	%

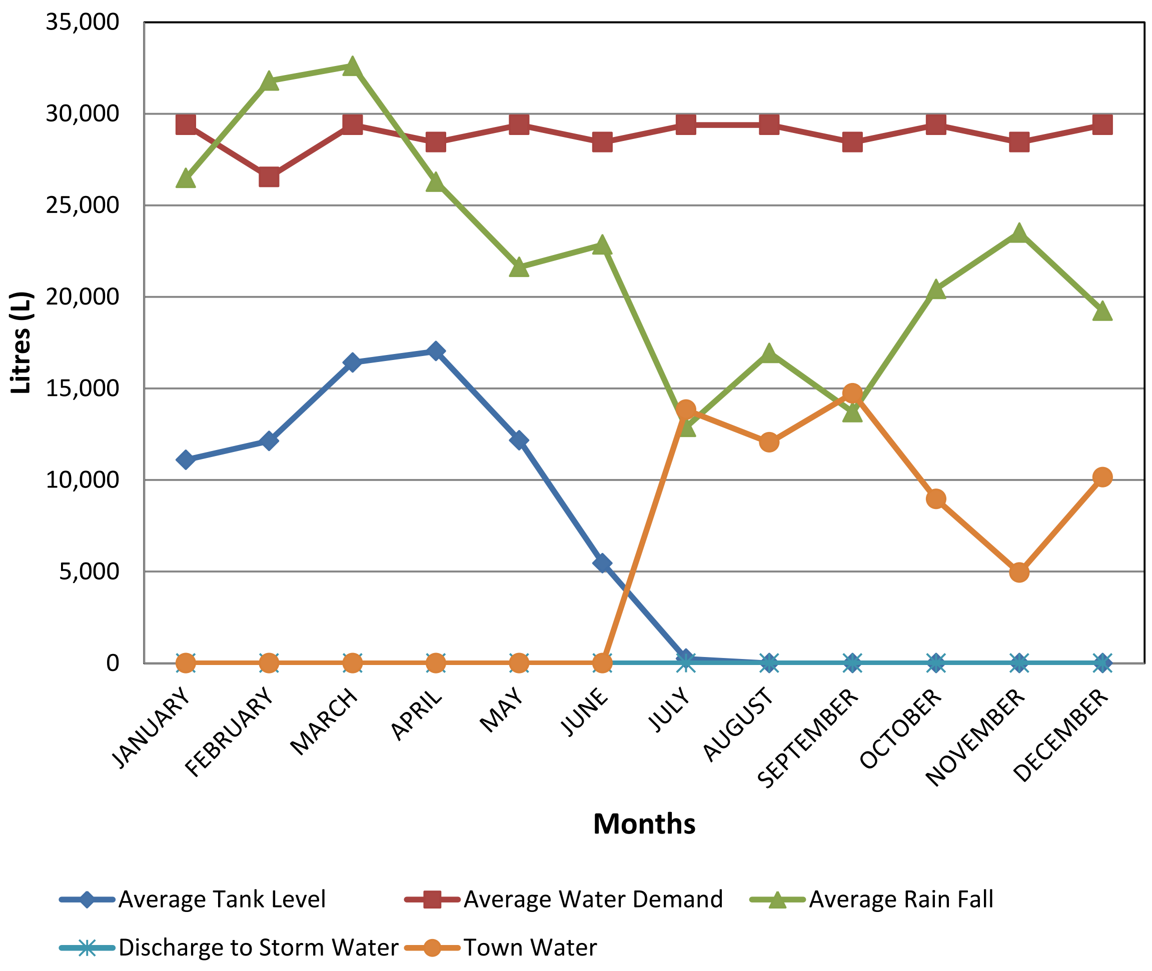

Figure 42: Water Analysis Results - Case Study B

The following results indicate that a 25,000L rain water tank is sufficient in supporting a high percentage of the development's water needs over a 12-month period. In this case, increasing the rainwater capacity will not result in any significant reducing in demand from town-water, this is a resultant of the catchment area. The rainwater tank never becomes completely full, and therefore adding a greater tank will result in a similar town water demand. To further reduce demand on town water, a greater catchment area needs to be captured in the rainwater tank. The current catchment area is 203sqm, 75sqm less then case study A. This as-built system reduces the demand on town-water by 281,350 L. The variation between the 'Captured Rainwater' (268.4kL), and the 'Yearly Rain Water Used (by development)' (281,350kL) is the initially assumed, half-full rainwater tank.

The total as-built system (rainwater tank, treatment unit and water pump) for this case study cost approximately $7,500 including GST (AUS) installed.

7.5.3 Life Cycle Analysis (eTools)

The Life Cycle Analysis was conducted to determine the total carbon footprint for each case study over their life time. In addition, each case study was compared against a national residential benchmark and the corresponding Building Code of Australia (BCA) compliant design for each case study project. The results were calculated using the online Life Cycle Design tool 'eTools' (eTools, 2014).

For each case study the total 'Global Warming Impact' represents the total associated mass of CO_2-equivalent generated over the total life of the development. This includes assembly, construction, materials, operation, maintenance, and dismantle/recycling. The 'As-Built' case study designs represent the constructed design, and are compared, with reference to their corresponding BCA compliant design and national residential benchmark, by their respective mass of CO2-eq/year/occupant unit.

The national residential benchmark used for comparison was derived by eTools, and is named "Residential Dwelling Mix AU Res Ave 2013 Code Compliant (10 Dwellings)". The benchmark has an estimated design life of 54 years, and a maximum durability of 50 years. In addition, the residential benchmark has a total impact of 4205kg CO2-eq/year/occupant (combining total embodied and operational carbon equivalent).

'Design Embodied Carbon' represents all of the carbon equivalent needed to assemble, manufacture, construction and dismantle/recycle the development. 'Design Operational Carbon' represents all of the carbon equivalent needed to operate and maintain the development over its specified design life.

7.5.3.1 Tree House Case Study A

The 'As-Built' design for Case study A has a total global warming impact of 203,777kgCO2-eq. When compared to the national residential benchmark (NRB) of 1,135,350kg.CO2-eq, is a total reduction 89% over the life of the development. Per year, each occupant living in the development will have a carbon equivalent impact of 453kg.CO2-eq/year/occupant. The NRB has a carbon equivalent impact of 4,205kg.CO2-eq/year/occupant, and the corresponding BCA compliant design has a carbon equivalent impact of 2,932kg.CO2-eq/year/occupant - a 28% reduction compared to the NRB. Table 36

outlines the results and comparison between the as-built design to the corresponding BCA compliant design and the NRB.

The noted reduction in the total and yearly carbon equivalent impact for as-built Case Study A design are from:

- Design Embodied Carbon:
  - The recycled content within the building projects
  - The recyclability of the building projects used
  - Rigid Insulation, this inclusion added 2.06kg.CO2-eq/year/occupant
- Design Operation Carbon:
  - PV system (4.97kW), the incorporation of this system achieved a reduction of 1,290.0kg.CO2-eq/year/occupant (compared to the BCA compliant design)
  - Rain water treatment, the incorporation of this system achieved a reduction of 16.1kg.CO2-eq/year/occupant (compared to the BCA compliant design).
  - LCD lighting, the incorporation of LED lighting achieved a reduction of 363.0kg.CO2-eq/year/occupant (compared to the BCA compliant design).
  - Solar hot water system with gas boost and low flow shower heads, the incorporation of his hot water unit achieved a reduction of 417.6kg.CO2-eq/year/occupant (compared to the BCA compliant design).

Table 36: eTools Life Cycle Assessment Results - Case Study A

	National Residential Benchmark	Tree House - Case Study A: BCA Compliant Design		Tree House - Case Study A: As-Built Design	
	Carbon	Carbon	Reduction to Benchmark	Carbon	Reduction to Benchmark
Design Embodied Carbon	1,502	691	25%	**609**	**34%**
Design Operational Carbon	2,702	2,270	29%	**-156**	**105%**
Total Design	4,205	2,962	28%	**453**	**89%**
Note: All above 'Carbon' units are in 'kg.CO2-eq/year/occupant'					

There is a noted 9% increase in the design embodied carbon between the as-built design and BCA compliant design. This increase is attributed to the embodied energy contained with the

added services, i.e. PV panels, rainwater storage and treatment, solar hot water collectors and increased level of insulation. No changes were made to the interior finishes and furnishings.

The eTools certified report for this LCA design is located in APPENDIX L: Case Study A - Life Cycle Analysis.

7.5.3.2 Escarpment View Case Study B

The 'As-Built' design for Case study B has a total global warming impact of 403,091kg.CO2-eq. When compared to the national residential benchmark (NRB) of 1,135,350kg.CO2-eq, is a total reduction 64.5% over the life of the development. Each occupant living in the development will have an annual carbon equivalent impact of 1,612kg.CO2-eq/year/occupant - a 62% reduction compared to the NRB. The NRB has a carbon equivalent impact of 4,205kg.CO2-eq/year/occupant, and the corresponding BCA compliant design has a carbon equivalent impact of 3,159kg.CO2-eq/year/occupant - a 24% reduction compared to the NRB. Table 37 outlines the results and comparison between the as-built design to the corresponding BCA compliant design and the NRB.

The noted reduction in the total and yearly carbon equivalent impact for as-built case study A design are from:

- Design Embodied Carbon:
  - The recycled content within the building projects
  - The recyclability of the building projects used
  - Rigid Insulation, this inclusion added 1.40kg.CO2-eq/year/occupant
- Design Operation Carbon:
  - PV system (3.12kW), the incorporation of this system achieved a reduction of (compared to the BCA compliant design) -810.0kg.CO2-eq/year/occupant
  - Rain water treatment, the incorporation of this system achieved a reduction of (compared to the BCA compliant design) -32.3kg.CO2-eq/year/occupant.
  - LCD lighting, the incorporation of LED lighting achieved a reduction of (compared to the BCA compliant design) -343.0kg.CO2-eq/year/occupant.
  - Solar hot water system with gas boost and low flow shower heads, the incorporation of his hot water unit achieved a reduction of (compared to the BCA compliant design) -458.3kg.CO2-eq/year/occupant.

Table 37: eTools Life Cycle Assessment Results - Case Study B

	National Residential Benchmark	Tree House - Case Study B: BCA Compliant Design		Tree House - Case Study B: As-Built Design	
	Carbon	Carbon	Reduction to Benchmark	Carbon	Reduction to Benchmark
Design Embodied Carbon	1,502	627	59%	**691**	**54%**
Design Operational Carbon	2,702	2,565	5%	**921**	**66%**
Total Design	4,205	3,192	24%	**1,612**	**62%**
Note: All above 'Carbon' units are in 'kg.CO2-eq/year/occupant'					

As for Case Study A, there was noted 9% increase in the design embodied carbon between the as-built design and BCA compliant design. This increase is attributed to the embodied energy contained with the added services, i.e. PV panels, rainwater storage and treatment, solar hot water collectors and increased level of insulation. No changes were made to the interior finishes and furnishings.

The eTools certified report for this LCA design is located in APPENDIX M: Case Study B - Life Cycle Analysis.

7.5.4 Thermal Performance & Energy Consumption

The building energy performance simulation software used for each case study was DesignBuilder (DesignBuilder Software Australia, 2014). Each as-built case study was designed without any mechanical systems. However, the energy simulations were conducted as follows:

- Corresponding BCA Compliance Design - With basic HVAC (including natural ventilation - where required to suit NatHERS protocol)
- As-Built Design - With basic HVAC (including natural ventilation - where required to suit NatHERS protocol).

7.5.4.1 Simulation Configuration

This section outlines the key input variables to demonstrate how each case study performed with respect to the corresponding Building Code of Australia (BCA) compliant design. Each simulation was conducted in alignment with the guidelines of Nationwide House Energy Rating Scheme (NatHERS) protocols (Department of Industry, 2014).

<u>Design Condition Schedule and Internal Gains</u>

The simulations utilised the 'Simple HVAC System' and 'Scheduled Natural Ventilation' options in DesignBuilder, the 'simple HVAC system' does not have a defined size, and the performance of this system is only dependant on the coefficient of performance (COP). The free running simulations within DesignBuilder are dependent on the inputted schedule and rates. The schedules and rates used for the case study simulations can be found in Table 38.

Table 38: Design Conditions for Bedrooms, Living Spaces and Wet-Areas

Bedroom Schedules	Time	Fraction
HVAC System – Inc. mechanical ventilation (0.5L/s/m^2) – Heating set point 18°C, cooling set point 25.5°C	00:00am to 09:00am 09:00am to 04:00pm 04:00pm to 00:00am	1 0 1
Natural Ventilation – Control set point 20°C (10ac/h)	24hours	1
Occupancy (0.05 person/m^2)	00:00am to 07:00am 07:00am to 10:00am 10:00am to 00:00am	1 0 1
Lighting (2W/m^2) – With daylight control	00:00am to 08:00pm 08:00pm to 11:00pm 11:00pm to 00:00am	0 1 0
Kitchen, Living and Dining Room Schedules	**Time**	**Fraction**
HVAC System – Inc. mechanical ventilation (0.5L/s/m^2) – Heating set point 20°C, cooling set point 25.5°C	00:00am to 07:00am 07:00am to 00:00am	0 1
Natural Ventilation – Control set point 22°C (10ac/h)	24hours	1
Occupancy (0.05 person/m^2)	00:00am to 07:00am 07:00am to 09:00am 09:00am to 05:00pm	0 1 0.5

	05:00pm to 10:00pm	0.75
	10:00pm to 00:00am	0
Equipment Gain (13W/m^2) – No internal gain for dining room	00:00am to 07:00am	0.1
	07:00am to 08:00am	0.4
	08:00am to 06:00pm	0.1
	06:00pm to 07:00pm	1
	07:00pm to 10:00pm	0.25
	10:00pm to 00:00am	0.1
Lighting (4W/m^2) – With daylight control	00:00am to 07:00pm	0
	07:00pm to 09:00pm	0.6
	09:00pm to 05:00pm	0
	05:00pm to 10:00pm	1
	10:00pm to 00:00am	0
Laundry, Bathrooms and Attic Schedules	**Time**	**Fraction**
Natural Ventilation – Control set point 15°C (6ac/h)	24hours	1

7.5.4.2 Tree House Case Study A

For thermal modelling purposes, Case Study A was broken into 12 thermal zones - as shown in Figure 43 and Figure 44. The colours used within the figures represent the zone classification:

- Kitchen, Living and Dining Room
- Bedrooms
- Laundry and Bathrooms
- Attics / Voids

The zone volumes and floor area are summarised in Table 39**:** Summary of Case Study A Zone Floor Areas and Volumes.

Table 39: Summary of Case Study A Zone Floor Areas and Volumes

Zone	Name	Floor Area (m^2)	Volume (m^3)
1	Garage	60.0	150
2	Front Entry, Kitchen, Living, Dining, Hallway and Rumpus Room	148.0	394.0
3	Master Bedroom	24.0	65
4	Ensuite	5.5	16.3
5	Bedroom 1	14.5	41.7
6	Bedroom 2	10.6	28.4
7	Bedroom 3	11.1	27.5
8	Laundry	6.0	14.9
9	WC1	2.4	6.24
10	Bathroom	6.6	17.2
11	Cupboard Space	2.1	5.3
12	Cupboard Space	1.6	4.2
	Total	**292.4**	**770.71**
	Conditioned Total	**228.7**	**611.24**

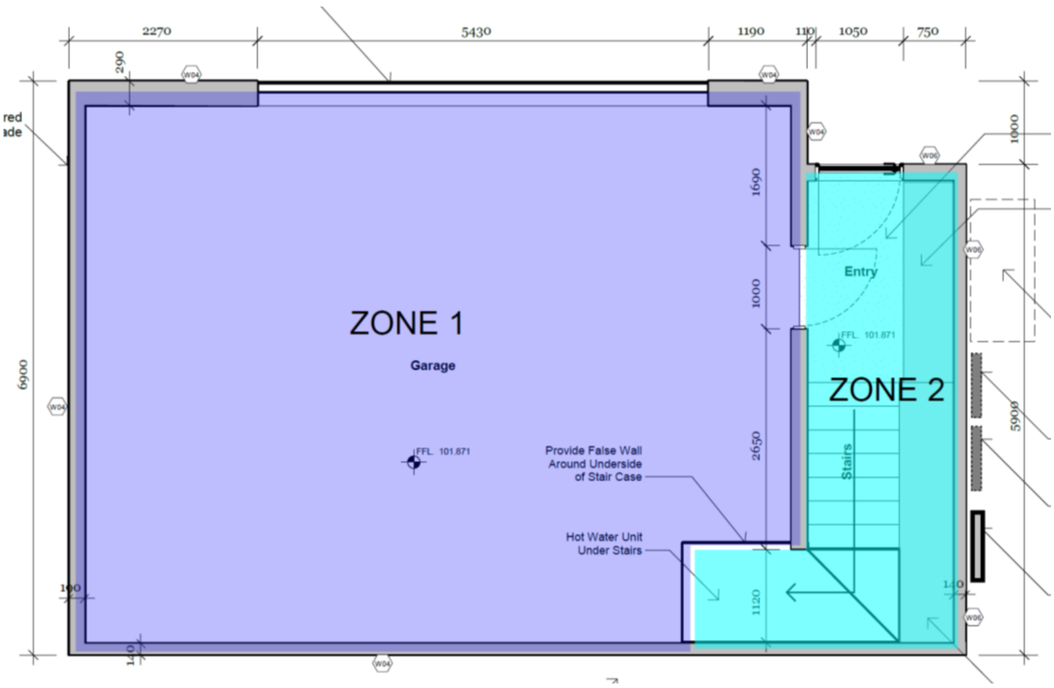

Figure 43: Ground Level Thermal Model Floor Plan - Case Study A

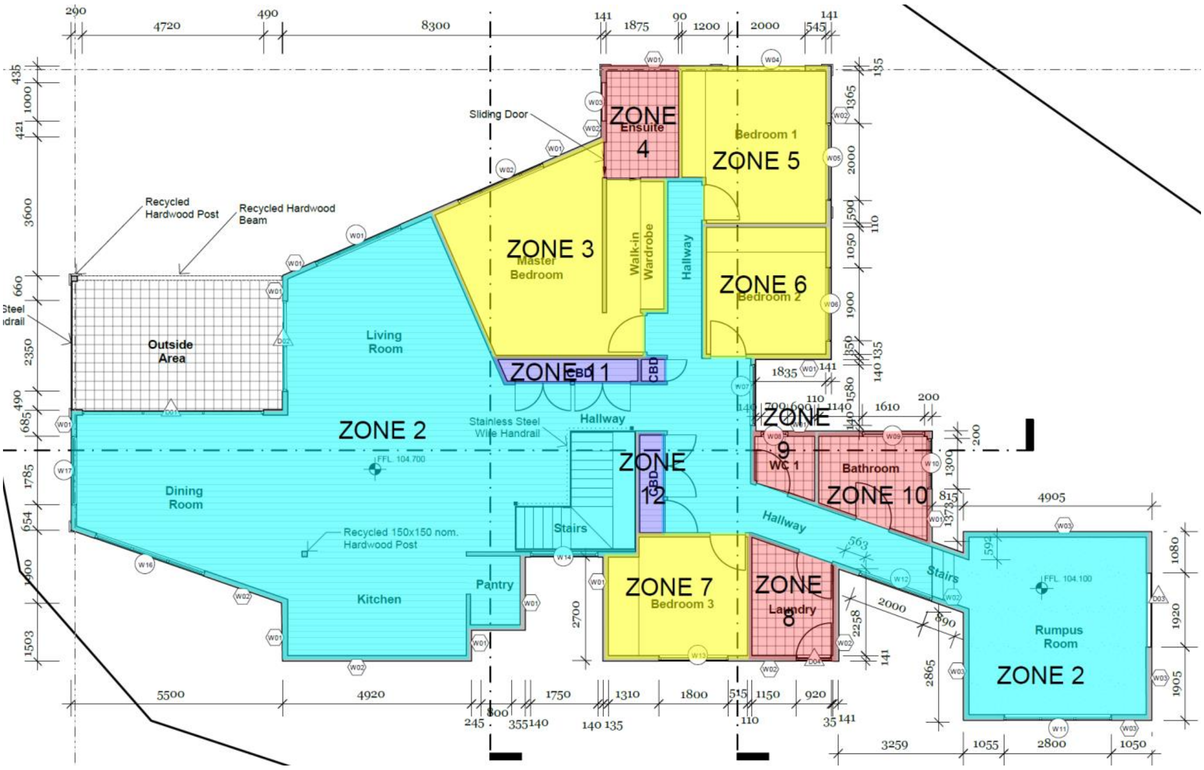

Figure 44: Level 1 Thermal Model Floor Plan - Case Study A.

Each floor, wall and roof system within this case study was given a reference code. The code referred to the buildings elements on the floor plans with the building details, which contains the composition of the building components - the details are located in APPENDIX J: Case Study A - Design Details. In addition, the thermal values used for each floor, wall, and roof component within this case study are located in Table 40, Table 41: Case Study A - Building Envelop, Thermal Resistance Values (FLOOR & ROOF), and Table 42. The glazing values were the average performance of all glazed window and door units.

Table 40: Case Study A - Building Envelop, Thermal Resistance Values (WALLS)

Wall Reference (reference on Drawings)	Location	Materials	R-Value	R-Value (BCA Compliant)
W01	Facade Wall (L1)	Refer to APPENDIX J: Case Study A - Design Details	3.99	2
W02	Facade Wall (L1)		3.95	2
W03	Facade Wall (L1)		4.01	2
W04	Facade Wall (GL)		1.5	1.5
W05	Facade Wall (GL)		0.25	0
W06	Internal Walls		2.19	0

Table 41: Case Study A - Building Envelop, Thermal Resistance Values (FLOOR & ROOF)

Reference (reference on Drawings)	Location	Materials	R-Value	R-Value (BCA Compliant)
F01	Floor (GL)	Refer to APPENDIX J: Case Study A - Design Details	0.36	0
F02	Suspended Floor (L1)		5.73	1.5
F03	Suspended Floor (L1)		5.93	1.5
F04	Suspended Floor (L1)		5.42	1.5
R01	Roof (all)		5.63	3.5

Table 42: Case Study A - Glazing, Performance Values

Glazing (reference on Drawings)	Location	Glazing	SHGC	U-Value	SHGC (BCA Compliant)	U-Value (BCA Compliant)
All	All	5clr tgh/12arg/5clr tgh (typical)	0.58	3.5	0.60	5.7

Note: Aluminium frames (unbroken)

7.5.4.3 Escarpment View Case Study B

For thermal modelling purposes, Case Study B was broken into 15 thermal zones - as shown in Figure 45 and Figure 46. The colours reference used within the figures represent the zone classification:

– Kitchen, Living and Dining Room

– Bedrooms

– Laundry and Bathrooms

– Attics / Voids

The zone volumes and floor area are summarised in Table 43**:** Summary of Case Study B Zone Floor Areas and Volumes.

Table 43: Summary of Case Study B Zone Floor Areas and Volumes

Zone	Name	Floor Area (m^2)	Volume (m^3)
1	Garage	44.0	114.4
2	Front Entry, Kitchen, Living, Dining, Hallway and Rumpus Room	98.87	259.2
3	Entry	5.1	13.8
4	Guest Bedroom	9.1	23.7
5	GL Bathroom	3.3	8.6
6	GL WC1	2.0	5.4
7	Laundry	6.4	16.6
8	GL Cupboard	3.4	9.2
9	Master Bedroom	17.2	46.5
10	Study	5.4	14.6
11	Bedroom 2	14.2	38.3
12	Bedroom 1	13.4	36.2
13	L1 Bathroom	8.9	24.0
14	L1 WC2	2.1	5.7
15	Walk-in Wardrobe / Cupboard	5.6	15.1
	Total	**238.97**	**631.30**
	Conditioned Total	**185.97**	**492.60**

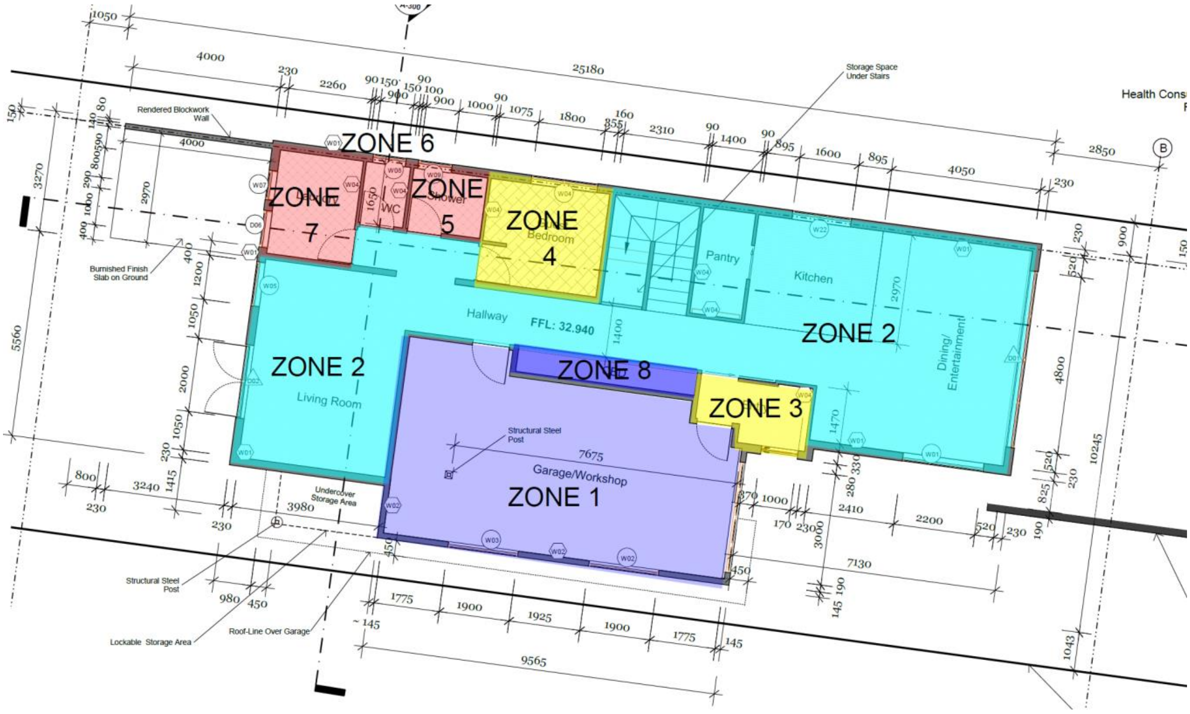

Figure 45: Ground Level Thermal Model Floor Plan - Case Study B.

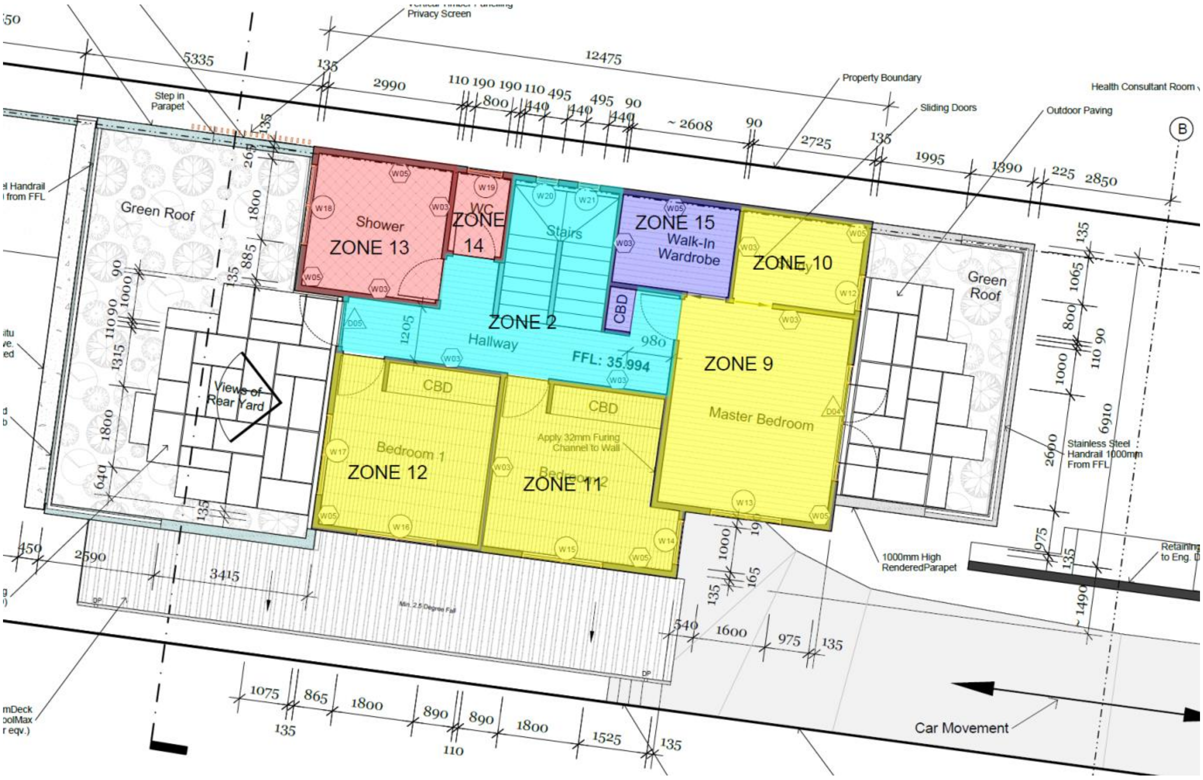

Figure 46: Level 1 Thermal Model Floor Plan - Case Study B.

Each floor, wall and roof system within this case study has a reference code. The code refers to the buildings elements on the floor plans with the building details, which contains the composition of the building components - the details are located in APPENDIX K: Case Study B - Design Details. In addition, the thermal values use for each floor, wall, roof and glazing component within this case study are located in Table 44, Table 45, and Table 46.

Table 44: Case Study B - Building Envelop, Thermal Resistance Values (WALLS)

Wall Reference (reference on Drawings)	Location	Materials	R-Value	R-Value (BCA Compliant)
W01	Facade Wall (GL)	Refer to APPENDIX K: Case Study B - Design Details	3.9	2
W03	Clinic Facade Wall (GL)		0.5	0
W05	Facade Wall (Level 1)		3.65	2
W04	Internal Walls		2.19	0

Table 45: Case Study B - Building Envelop, Thermal Resistance Values (FLOOR & ROOF)

Reference (reference on Drawings)	Location	Materials	R-Value	R-Value (BCA Compliant)
F1	Ground Floor	Refer to APPENDIX K: Case Study B - Design Details	0.36	0
F2	Suspended Floor (inside)		5.73	0
F2	Suspended (outside)		5.93	1.5
R1	Roof (racked)		5.63	3.5
R2	Roof (pitched)		6.92	3.5

Table 46: Case Study B - Glazing, Performance Values

Glazing (reference on Drawings)	Location	Glazing	SHGC	U-Value	SHGC (BCA Compliant)	U-Value (BCA Compliant)
All	All	5clr tgh/12arg/5clr tgh (typical)	0.55	2.2	0.60	5.7

Note: Hybrid frames, fibreglass outside and timber inside (broken)

7.5.4.4 Simple HVAC Model Results: As-Built Versus BCA Design

Each case study was modelled using a simple HVAC system, for both the as-built design and the BCA compliant design. The results were used to compare the added advantages of the increase in insulation and glazing properties against the increase in initial capital cost on thermal comfort and building performance.

Case Study A

As expected, an increase in thermal and glazing performances increased the thermal performance of Case Study A. For the as-built design, the yearly combined heating and cooling demand was estimated to be 31.0 MJ/m^2 which equates to a NatHERS star rating of 7.6. The BCA compliant design had a yearly heating and cooling demand of 57.7 MJ/m^2 which equates to a NatHERS star rating of 5.5. In NSW a new home is required be at least 4-stars (or a combined heating and cooling load equal to or less than 88 MJ/m^2/year). The BCA compliant design demonstrated a reduction of 30.3 MJ/m^2/year (compared with the 4 star requirement), whereas the as-built represented an additional reduction of 26.7 MJ/m^2/year. Table 47 outlines the yearly comparison between the as-built design and BCA compliant design and Figure 48 give a monthly breakdown of the heating and cooling demands. The greatest increase in performance is noticed in the heating demands during the winter months of the year (June, July and August).

Table 47: Case Study A - Annual Heating and Cooling Demands

	As-built design	BCA Compliant Design
Heating Load	22.5 MJ/m^2/year	28.8 MJ/m^2/year
Cooling Load	8.6 MJ/m^2/year	28.9 MJ/m^2/year
Combined H&C Load	31.0 MJ/m^2/year	57.7 MJ/m^2/year
NatHERS Rating	7.6	5.5

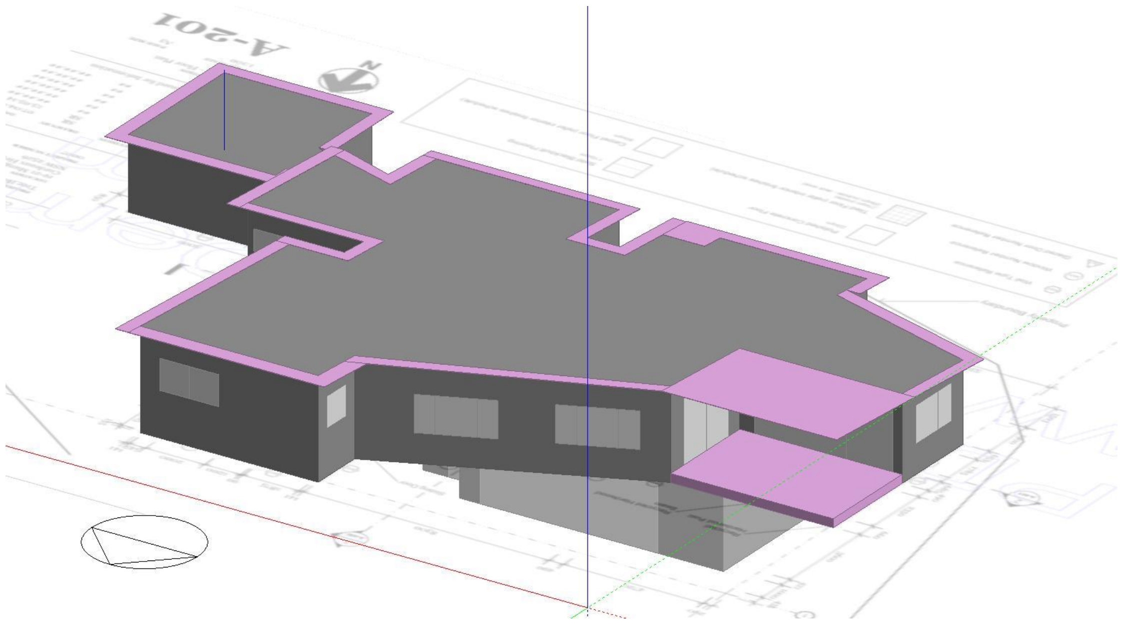

Figure 47: Case Study A - DesignBuilder Isometric Image.

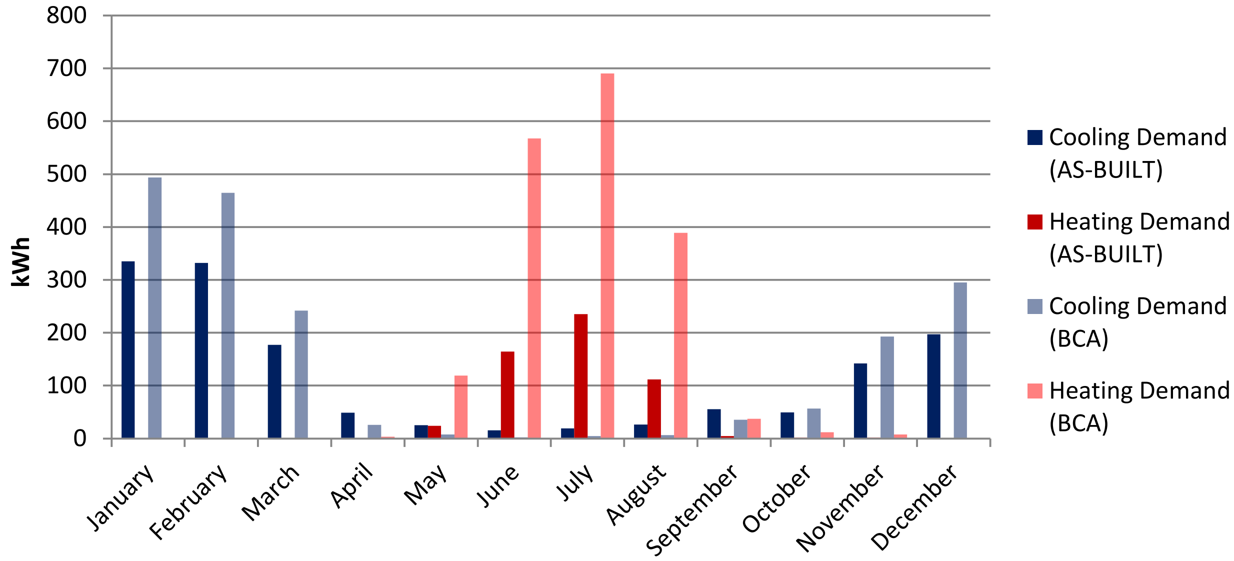

Figure 48: Case Study A - Heating and Cooling Demands (monthly breakdown).

<u>Case Study B</u>

Case Study B had a noticeable reduction in both heating and cooling demand with the increased in thermal and glazing performances for the as-built design. The as-built design has combined yearly heating and cooling demand of 23.6 MJ/m^2 which equates to a NatHERS star rating of 8.1. The BCA compliant design had a yearly heating and cooling demand of 56.6 MJ/m^2 which equates to a NatHERS star rating of 5.6. As stated, a new home in NSW requires a minimum star rating of 4 (or a combined heating and cooling load equal to or less than 88 MJ/m^2/year). The BCA compliant design demonstrates a reduction of 31.4 MJ/m^2/year (compared with the 4 star requirement), whereas the as-built represents an additional reduction of 33.0 MJ/m^2/year. Table 48 outlines the yearly comparison between the as-built design and BCA compliant design and Figure 50 give a monthly breakdown of the heating and cooling demands.

Table 48: Case Study B - Annual Heating and Cooling Demands

	As-built design	BCA Compliant Design
Heating load	6.8 MJ/m2/year	20.8 MJ/m2/year
Cooling load	16.8 MJ/m2/year	35.8 MJ/m2/year
Combined H&C load	23.6 MJ/m2/year	56.6 MJ/m2/year
NatHERS Rating	8.1	5.6

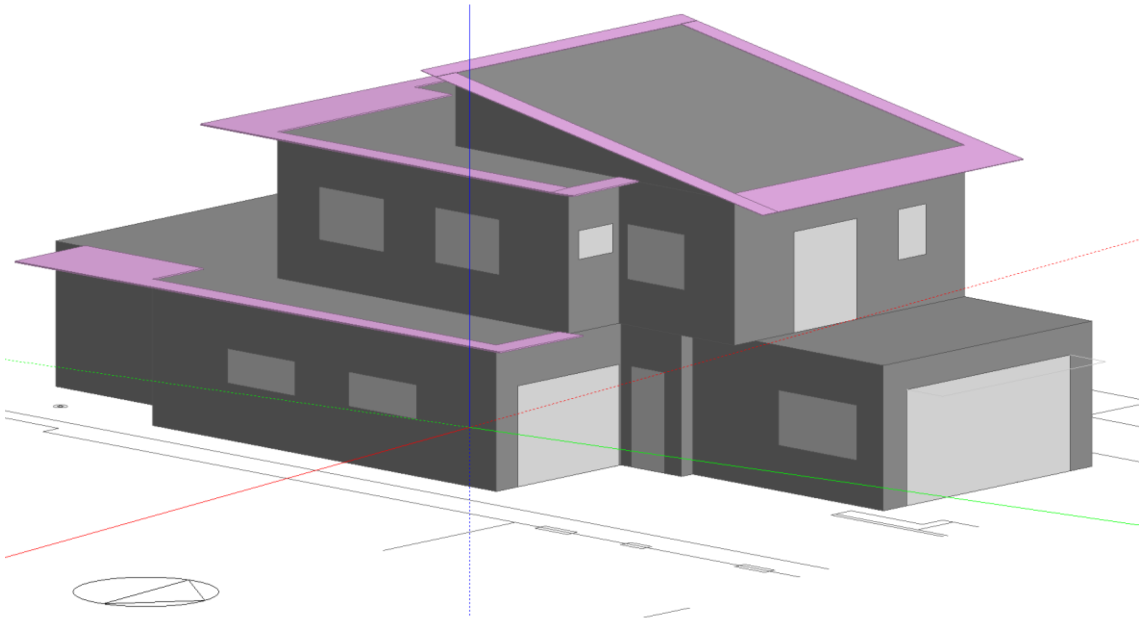

Figure 49: Case Study B - DesignBuilder Isometric Image

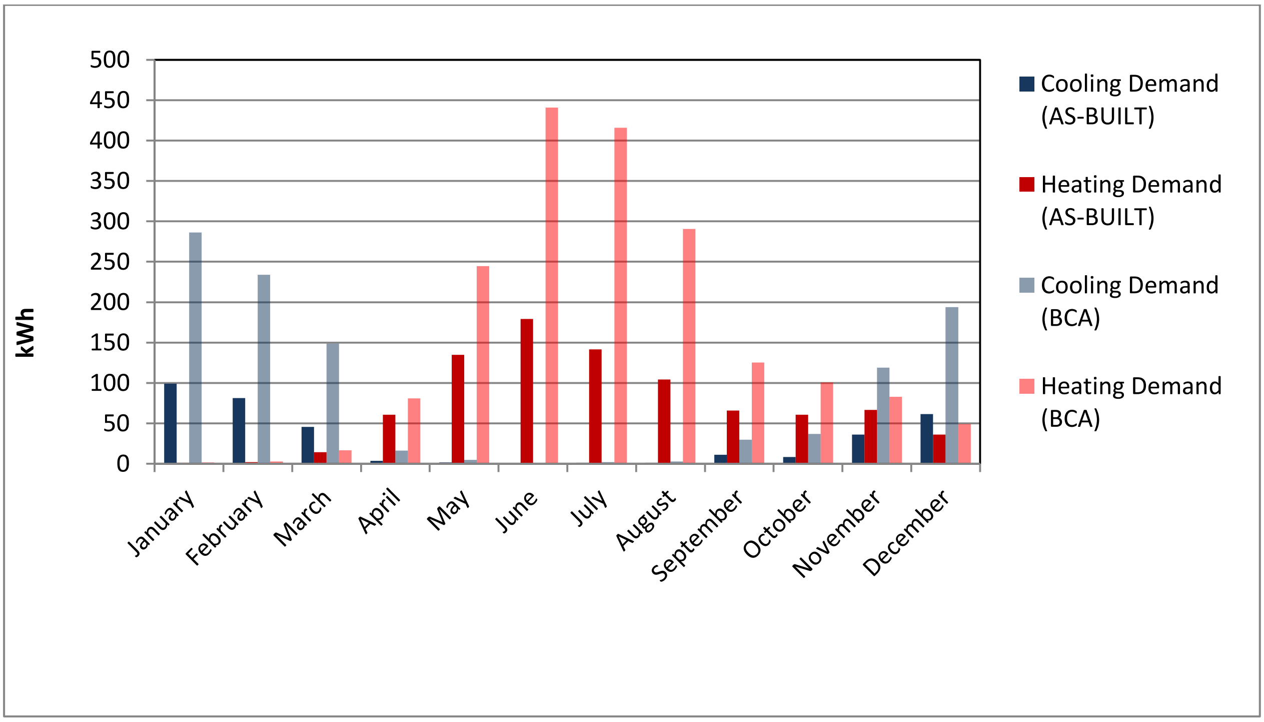

Figure 50: Case Study B - Heating and Cooling Demands (monthly breakdown)

7.6 Chapter Summary

The case study results show that ProSustain was able to assist in the delivery and validation of more sustainable houses. The aim of ProSustain was to develop a management framework to better initiate, plan and manage the delivery of sustainable houses through targeted objectives. During the design process the main focus was placed on the social requirements of the client, and financial and environmental considerations were secondary. Bringing the financial significance towards social and environmental decisions to the front allowed the client and author to make calculated decisions that resulted in balanced and sustainable outcomes.

Both case studies had an additional capital expenditure of approximately 30% over their original budgets. However this was a result of managing the social requirements of the home with realistic financial expectations, and not a mismanagement of the project budget. The method adopted by the author allowed for justification of project expenditures, which in turn added value in the decision making process. It might have been expected that designing and construction to BCA requirements would result in a house that surpasses their 4-star requirement and the national LCA benchmark. However, the results show that an additional 50% reduction in heating and cooling load can be achieved, as well as an 80 to 90% reduction in the carbon footprint over the life-time of the development. To achieve such results, consideration must be given to environmental factors pertaining to proposed materials and systems. In addition, methods to reduce operational demands were demonstrated, all of which resulted in a relevantly small increase in capital expenditure.

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

In this chapter, a summary of the study is presented, consisting of two parts. The first part outlines the research conclusions and demonstrates how the research aims and objectives were achieved. The second part outlines recommendations for future research.

8.1 Conclusion

This thesis details the successful development and testing of ProSustain, a new project management framework for the delivery of sustainable residential developments. The implementation of ProSustain has demonstrated that delivering sustainable houses is possible with current technologies, knowledge, experience and supply chains. The success of ProSustain stems from bringing a tailored project management framework together with core sustainability objectives into the residential development industry. This is the first step in the overall development of the framework, and further implementation and refinement is required before the framework can be finalised.

The objectives of this research have been addressed and met during the development of ProSustain.

8.1.1 Investigate sustainable residential building development

The first research objective was to investigate sustainable residential development. The literature review revealed the significant impact our built environment has on natural resources and energy demands, which makes efforts to reduce these impacts a high priority. The review demonstrated that the delivery of sustainable developments can generally only be achieved if clear objectives are defined, monitored and executed. Balancing the outcomes of sustainable objectives against the three themes of sustainability, social, financial and environmental, will, in principle, result in an overall sustainable outcome for the development.

Practical examples of sustainable houses were reviewed and presented as demonstrations of what is currently possible. These examples represent, through extensive design and

construction diligence, a collection of different, yet highly innovative solutions to reducing society's impact on the natural environment. Capturing the process by which these projects were delivered was critical to the successful development of ProSustain.

8.1.2 Determine key project management considerations for successful delivery of sustainable building projects

The second research objective was to determine key project management considerations for the successful delivery of sustainable building projects. Traditional thinking separated project management practices from the delivery of sustainable outcomes in building developments. This mindset and approach relies on the implementation of sustainable rating tools to achieve innovative sustainable results. More recently, researchers have recognised the significance of project management practices to influence and deliver of sustainable outcomes. To the knowledge of the present author, ProSustain is the first practical integration of sustainability into the project management practices in the residential marketplace. The key findings were that: project management should be based on the industry best practice - PMBOK guide; sustainability objectives need to be considered at the project commissioning stage; and an industry-specific risk and stakeholder management approach should be used.

8.1.3 Investigate sustainability awareness of architects, designers and builders and how it influences their management of projects and decision-making

The third research objective was to investigate the awareness key stakeholders in the residential building industry have concerning sustainability, project management and decision-making. The results illustrated several key similarities and differences. A sustainable home represents the 'right' balance between the client's social needs (as expressed from the perspective of the client, i.e. form and function), financial constraints and the feasibility of various incorporated environmental/sustainable features. Developing the client brief was considered an important aspect of the client-professional interaction, although typically only the client's social needs were captured and considered. However, how each need, constraint and feasible option is considered varied between the different stakeholders. Managing decision-making around project objectives, project options and project outcomes needs to be championed to ensure the right balance is achieved.

There was a noted disconnect between project risks and project failures amongst the professional interviewees. Understanding the link between risks and failures is seen as critical to the effective management and delivery of project outcomes. Identifying and managing project risks mitigate partial or complete project failures – where failure is defined as not achieving project outcomes.

The design professional interviewees indicated that sustainable validation (of sustainable features) was not an important aspect of their design consultancy role. However, the validation of project outcomes is critical in ensuring the project objectives are met. Without validation, lessons learnt will never be effectively captured and reapplied to future projects. This was a key finding in the development of ProSustain.

8.1.4 Develop and validate a project management framework for the successful delivery of sustainable residential developments through case studies

The fourth and fifth objectives were to develop and validate a project management framework to successfully deliver sustainable residential developments. ProSustain was developed based on knowledge gained from the literature review, practical case studies and applying action research during the application of the unpublished framework to two research case studies.

The case study results demonstrate that ProSustain is able to assist in the delivery and validation of sustainable residential developments. The rationale behind the development of ProSustain was to develop a management framework to better initiate, plan and manage the delivery of sustainable residential developments through targeted objectives. The outcomes of the two houses demonstrated a 50% reduction in heating and cooling loads, and an 80 to 90% reduction in the carbon footprint over the life of the development, pointing to the effectiveness of ProSustain.

The core result of this study is that project management can assist in the successful delivery of sustainable residential developments. The case study results also demonstrate large reductions in operational demands and life-cycle impacts of the developments. ProSustain therefore provides a solid foundation for the development of a new field of sustainable project management practices.

8.2 Recommendations

During the implementation of ProSustain, several aspects were considered that could further assist in the delivery of sustainable residential developments. Stakeholder management and key project stakeholders are considered by ProSustain, however an understanding of stakeholder influences in the residential development market is currently an area where there are few results published in the literature. Gaining a better understanding of key stakeholder influences in the residential development industry would allow for the development of effective stakeholder management approaches, and provide a greater insight into associated direct and indirect project risks.

A further recommendation is the development of a standardised method to prepare the 'client brief'. The client brief is critical to ProSustain, and to residential developments more generally, as the brief carries the sustainable objectives of the project, with specific emphasis on tailoring the objectives to the client’s social requirements. The method must also include forecasting realistic project outcomes, to ensure the commissioned project meets the sustainable objectives. It has been shown that involving all key stakeholders at this point will lead to realistic project outcomes.

Another recommendation for future work is in the development of a decision making protocol for material, system and technology selection. The decisions associated with each product directly influence the final constructed outcome of the building. This specific decision making protocol would complement the decision making protocol outlined in ProSustain by focussing on product selection rather than project direction.

The final recommendation is to perform a wider, industry-based, application of ProSustain. The application would be by external professionals under guidance, applying the framework to a variety of residential developments. This would provide extensive data on the usage of ProSustain in real-world applications, which can then be used to shape the next iteration of the ProSustain framework.

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APPENDIX A: SUMMARY OF SUSTAINABLE RATING TOOLS

Sustainable Rating Tools:

LEED

Leadership in Energy and Environmental Design (LEED) was designed by the U.S. Green Building Council (USGBC) and launched in 2000. LEED is a performance based, sustainable building rating tool for commercial, institutional and high-rise residential new construction and extensive renovation projects (Akadiri, 2011). LEED has emerged and since adopted in the USA as the green building standard. Since the introduction of LEED, the green building movement has grown rapidly, with the number of LEED certified buildings doubling each year. In addition, the LEED framework has been used as the basis for the development of other sustainable rating tools around the world (Kibert, 2003). LEED has a sliding scale, across multiple criteria. The criteria include: Sustainable Sites, Materials and Resources, Water Efficiency, Energy and Atmosphere, and Indoor Environment Quality. For each criteria, there is a maximum number of credits that can be achieved. The number of credits achieved, summed across each criteria dictate the overall LEED rating. There are three levels of certification: Silver, Gold and Platinum (Iyer-Raniga and Wasiluk, 2007).

However Larsson (1999) states, while LEED is well accepted and adopted by the design and construction community because of its simplicity, its completeness in assessing building performance is in doubt.

BREEAM

Building Research Establishment Environmental Assessment Method (BREEAM) was the world's first sustainable rating tool, and remains the most widely used (Larsson, 1999). BREEAM was introduced in 1990 by the Building Research Establishment (BRE) (BRE Group, 2014), and developed with in collaboration with private developers throughout the UK (Akadiri, 2011). Since 1990, BREEAM has continually updated. The BREEAM system initially launched as a credit award system for new office buildings. A certificate of the assessment result is awarded to the individual building based on a single rating scheme of fair, good, very good or excellent. In order to gain a graded certificate, the individual building was evaluated against environmental criteria and building performances (Akadiri, 2011).

The evaluation criteria are divided across nine categories (Iyer-Raniga and Wasiluk, 2007), they are:

1. Management
2. Health & Comfort
3. Energy
4. Transport
5. Water Consumption
6. Materials
7. Land Use
8. Site Ecology
9. Pollution

This rating system can be carried out as early as the project initiation stages, or concept design stage, and can be continued throughout the life of a buildings (Iyer-Raniga and Wasiluk, 2007). At which time, investigation results can be fed back into the design development stage, to allow a refinement of overall design (Larsson, 1999).

BREEAM has been recognised worldwide, and as far as Australia, Canada and Hong Kong, with them developing their own sustainable rating tools largely based on the BREEAM methodology.

<u>Living Building Challenge</u>

The Living Building Challenge (LBC) is an international sustainable building certification program that was created in 2006 by the non-profit International Living Future Institute. It is described by the Institute as a philosophy, advocacy tool and certification program that promotes the most advanced measurement of sustainability in the built environment (International Living Future Institute, 2014). It can be applied to development at all scales, from buildings (inc. residential) – both new construction and renovation - to infrastructure, landscapes and neighborhoods, and is established as a more rigorous green certification scheme then LEED, Green Star or BREEAM. The added level if difficulty to achieve LBC has been attributed to two key factors, more rigorous and high level of standard to achieve each petal (also known as category by other rating systems), and the linking of design and construction performances to actual building performances. Therefore requiring a development to achieve and validate the excepted building performances during operation.

Green Star

Green Star was launch in 2003, and was developed by the Green Building Council of Australia (GBCA, 2014). The evaluating framework used by Green Star is based on the framework used by the LEED system. The difference between the two rating systems is the number of categories, and their associated definitions and available 'credits' (Iyer-Raniga and Wasiluk, 2007). Other differences are: the ranking scale (Green Star uses 'stars' - the greater the number of stars the more sustainable the outcome, and LEED uses 'medal' based system), and the LEED system can review and provide 'progressive' achievement as the project is being design and constructed. Whereas Green Star can only be evaluated once the building has been finalised. Green Star comprises of nine different categories, they are: Management, Indoor Environmental Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions and Innovation. Each of these categories comprises is different credits, each credit possible 'points' to achieving another 'star'. Some credits are mandatory for a project receive any level of Green Star recognition (GBCA, 2014).

Energy Modelling Tools:

National Australian Built Environment Rating System (NABERS)

NABERS is a post occupational energy and water measuring tool. This tool was developed in 1999 by the Federal Department of Environmental and Heritage (DEH) to ensure a consistent approach to measure and evaluate actual building performances, which provides owners and building managers clear indication of how well the building is operating (Iyer-Raniga and Wasiluk, 2007, Office of Environment and Heritage, 2014). NABERS comprises of four rating tools, they are: NABERS Energy, NABERS Water, NABERS Waste and NABERS Indoor Environment. These tools can be used to rate commercial office space, shopping centres, hotels and residential homes (Office of Environment and Heritage, 2014).

From the input data, NABERS uses current unit rates and algorithms to calculate the annual operational carbon emission for the development (Office of Environment and Heritage, 2014).

AccuRate

AccuRate was developed by Commonwealth Scientific and Industrial Research Organisation (CSIRO) in consultation with the Australian Greenhouse Office and Hearne Scientific

Software (Iyer-Raniga and Wasiluk, 2007). The AccuRate modelling software is powered by the Chenath engine, which was validated in 2004 against the international standard ANSI/ASHRAE 140-2001 (Department of Industry, 2014). AccuRate does not have a graphical user interface, but includes a ventilation model, which helps the software address rating homes in tropical and sub-tropical areas. In addition, the software more accurately reflects material properties in reality (Iyer-Raniga and Wasiluk, 2007).

BERS Professional

"BERS is a simulation tool that analysis the monthly seasonal or annual thermal performance of Australian houses in climates ranging from alpine to tropical. It." (Iyer-Raniga and Wasiluk, 2007)

BERS Professional was developed by Solar Logic, and is accredited under the NatHERS star rating scheme, and uses the AccuRate Chenath engine (Solar Logic, 2014). Iyer-Raniga and Wasiluk (2007) explains that BERS' user interface is graphic based, and therefore makes it easy to design, simulate and immediately and visually see impact of design decisions.

FirstRate

FirstRate was developed by Sustainable Energy Authority of Victoria (now, Sustainability Victoria). FirstRate is a residential thermal performance assessment software. It is used by accredited professionals within industry to rate the energy efficiency compliance of residential dwellings, and ensure they meet the 6 Star Victorian thermal performance requirements (Sustainability Victoria, 2014).

FirstRate has undergone an upgrade, and have released FirstRate5. It has a "...graphic user interface that enables designers and thermal performance assessors to quickly generate the geometry of a home by tracing over building floor plans... and can be used to rate an existing design or as an interactive tool to optimise it for or beyond compliance." (Sustainability Victoria, 2014)

Like BERS Professional, FirstRate integrates the AccuRate calculation engine, Chenath, to generate the home rating.

Life Cycle Analysis Tools:

Ecospecifier Global

Ecospecifier Global is a database of over 6,700 certified and verified building projects. The database has a free to use search tool, which comprises LCI information on independently verified and certified products. For a product to be verified, it must be reviewed against by a third party. LCARate is the third party assessor, this process is based (and compliant) on ISO 14024 Type 1 standard, ISO 14040 Life Cycle Assessment (LCA) standard and ISO 14025 and EN 15804 (Ecospecifier, 2015). Once certified, each product is given an 'GreenTag' lable. A GreenTag is a rating of the products sustainability credentials against six criterions: building synergy, health and ecotoxicity, biodiversity, LCA score, GHG (embodied), and social responsibility. Once the product is evaluated, it is placed against a rating scale, in descending order: platinum, gold, silver and bronze (Green Tag, 2015). A Green Tag is also a recognised data source of product data for Green Star and LEED building rating tools.

LCADesign

LCADesign was developed by CRC Construction Innovation in conjunction with Commonwealth Scientific and Industry Research Organisation (CSIRO). LCADesign was one of the first Building Information Modelling (BIM) tools based on delivering a detailed life cycle assessment to help design professionals make informed decisions on long-term impacts of the buildings assembly, embodied and operational carbon footprint. In addition, LCADesign is equiped with reading IFC files from 3D modelling software packages, allowing automatic product information and quantity take-offs (Tucker et al., 2003). The tool was launched in Australia in 2010, with the purpose of delivering a faster, more user-friendly method to assessing a building LCA (CRC Construction, 2006).

APPENDIX B: UOW ETHICS APPROVAL LETTER

UNIVERSITY OF WOLLONGONG

APPROVAL LETTER
In reply please quote: HE14/296

18 July 2014

Mr Scott Redwood
Sustainable Buildings Research Centre
Building 237, UOW Innovation Campus
University of Wollongong NSW 2522

Dear Mr Redwood

Thank you for your response dated 16 July 2014 to the HREC review of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number:	HE14/296
Project Title:	Project Management Theory for Delivering Sustainable Residential Developments
Researchers:	Mr Scott Redwood, Professor Timothy McCarthy, Dr Lip Teh
Documents Approved/Noted:	
	-Ethics Application Form (Received 8/7/14)
	-Interview Request Letter- Professionals (June 2014)
	-Consent form for participants- Professionals (Received 8/7 /14)
	-Participant Information Sheet- Professionals (Received 8/7/14)
	-Interview Outline Form- Professionals (Received 8/7/14)
	-Interview Request Letter- General Public + case study (June 2014)
	-Consent form for participants- Gen Public + case study (Rec 8/7 /14)
	-Participant Information Sheet- Gen Public + case study (Rec 8/7/14)
	-Interview Outline Form- General Public + case study (8/7/14)
	-Interview Request Letter- General Public (June 2014)
	-Consent form for participants- General Public (Received 8/7 /14)
	-Participant Information Sheet- General Public (Received 8/7/14)
	-Interview Outline Form- General Public (8/7/14)
Approval Date:	17 July 2014
Expiry Date:	16 July 2015

The University of Wollongong/Illawarra Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research*. The HREC has reviewed the research proposal for compliance with the *National Statement* and approval of this project is conditional upon your continuing compliance with this document.

Ethics Unit, Research Services Office
University of Wollongong NSW 2522 Australia
Telephone (02) 4221 3386 Facsimile (02) 4221 4338
Email: rso-ethics@uow.edu.au Web: www.uow.edu.au

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/human/index.html. This report must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely

Professor Kathleen Clapham
Chair, Social Sciences
Human Research Ethics Committee

APPENDIX C: PARTICIPANTS INVITATION LETTER

June 2014

UOW Sustainable Buildings Research Centre Interview Request

Dear ... ,

I am inviting you to participate in our research to better understand the current domestic sustainable development market, more specifically, how best to manage and deliver sustainability within our homes. The project aims to develop a project management theory that will help design and construction professionals deliver sustainable homes.

I am conducting this research as part of my Masters studies under Professor Timothy McCarthy at the University of Wollongong's Sustainable Buildings Research Centre (SBRC). I am interested in gauging your perceptions and knowing your opinions regarding sustainability within our built environment. Also, how you identify and deliver sustainability for your clients in their developments, and more specifically, management techniques you may use, and decision making methods you apply. How effective you find these approaches, how do you determine if a project is a success and/or failure with respect to project objectives. Therefore, I am requesting an opportunity to conduct a face-to-face interview with you. The interview may take around 45 minutes and a list of questions/topics will be forwarded to you prior to the interview.

With your permission your interview will be recorded to aid in transcription. All information will be securely stored, and strict confidentiality will be maintained at all times. No quotes or identifying information will be published or shared without your prior written consent. The research, possibly including some direct quotes, may appear in my PhD thesis, and possibly in other published forms, subject to your consent.

Should you have any questions, please don't hesitate to contact me. I look forward to your favourable response.

Regards,

Scott Redwood | Masters by Research candidate
Sustainable Buildings Research Centre
University of Wollongong | NSW | 2522
T + 61 405 025 597 **E** sar400@uowmail.edu.au

Sustainable Buildings Research Centre (SBRC), Faculty of Engineering
Building 237, Innovation Campus, University of Wollongong, Squires Way, North Wollongong, NSW 2522 Australia
Telephone: (61 2) 4221 8111 sbrc@uow.edu.au http://sbrc.uow.edu.au

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I am conducting this research as part of my Masters studies under Professor Tim McCarthy at the University of Wollongong's Sustainable Buildings Research Centre (SBRC). I am interested in gauging your perceptions and knowing your opinions regarding sustainability concepts within homes, and the processes that you went through in commissioning your home. Also, I am interested in how decision-making was justified (by relevant people) with reference to delivering the most sustainable outcome, how the process was managed, and how the overall outcome of the project was perceived.

I am requesting an opportunity to conduct a face-to-face interview with you. The interview may take around 15 to 20 minutes, and a list of questions/topics will be forwarded to you prior to the interview.

With your permission, your interview will be recorded to aid in transcription. All information will be securely stored, and strict confidentiality will be maintained at all times. No quotes or identifying information will be published or shared without your prior written consent. The research, possibly including some direct quotes, may appear in my Masters thesis and other published forms, subject to your consent.

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I am requesting an opportunity to conduct a face-to-face interview with you. The interview may take around 15 to 20 minutes, and a list of questions/topics will be forwarded to you prior to the interview. In addition, the use of sanitised information from your development, this information will be used as a case study for validation of the theory within this research.

With your permission, your interview will be recorded to aid in transcription. All information will be securely stored, and strict confidentiality will be maintained at all times. No quotes or identifying information will be published or shared without your prior written consent. The research, possibly including some direct quotes, may appear in my Masters thesis and other published forms, subject to your consent.

Should you have any questions, please don't hesitate to contact me. I look forward to your favourable response.

Regards,

Scott Redwood | Masters by Research candidate
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APPENDIX D: PARTICIPANT INFORMATION SHEET

SDRC SUSTAINABLE BUILDINGS RESEARCH CENTRE | UNIVERSITY OF WOLLONGONG

PARTICIPANT INFORMATION SHEET

Project Title: *Sustainability and Our Homes*

Participant: Professionals (architects, building designers and builders)

Purpose of the research
The aim of this project is to gain a better understanding of the existing industry standard around the management and decision making processed used in delivering sustainable homes. The researchers would like to receive feedback on their proposed project management theory for enhancement and adoptability.

Methods and demands on participants
If you choose to be involved in this study, you will be asked to participate in a semi-structured interview conducted by Masters student Scott Redwood. The interview will focus on your experience in delivering sustainable homes - more specifically, your perceptions concerning management techniques use, decision making methods applied, and the overall project monitoring. The interviewer will explain how your existing projects are conducted, if there are specific methods or tools used, how effective these methods are, how a project is deemed 'sustainable' and overall successful, and to critique the researchers proposed management theory based on your opinions and perceptions.

The interview is expected to take about 45 min and will be audio-recorded to ensure accurate transcription. You are invited to request a copy of the transcript, and to submit edits/revisions. The information from your interview, possibly including some direct quotes, which may appear in the Masters thesis of the interviewer, and academic journals, subject to your consent. You will be asked if you wish to be given a pseudonym if direct quotations from the transcribed conversations are used in the researcher's Master's thesis or scholarly publications.

Being a participant is voluntary, therefore each participant has the ability to withdraw from the study up to the date of the interview. The recorded responses to questions will be issued to the relevant participant to review, alter, and accept and/or disprove. If a response from the participant is not received within 28 days, the researchers will assume approval for the documented responses to the researchers questions.

Inconveniences and discomforts
The major inconvenience will be your time spent in the interview. Your involvement in the study is voluntary and you may withdraw your participation and any data that you have provided to that point.

The Project Organiser
This project is funded by the Sustainable Buildings Research Centre, University of Wollongong. If you have any enquiries about the project, or would like to volunteer to participate, please contact: Scott Redwood (0405 025 597; sar400@uowmail.edu.au). This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. If you have any concerns or complaints regarding the way this research has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Thank you for your interest in this study.

Prof Timothy McCarthy
Professor; Civil, Mining and Environmental (CME) University of Wollongong
10th June 2014

Sustainable Buildings Research Centre (SBRC), Faculty of Engineering
Building 237, Innovation Campus, University of Wollongong, Squires Way, North Wollongong, NSW 2522 Australia
Telephone: (61 2) 4221 8111 sbrc@uow.edu.au http://sbrc.uow.edu.au

PARTICIPANT INFORMATION SHEET

Project Title: *Management, Sustainability and Our Homes*

Participant: General Public (clients)

Purpose of the research
The aim of this project is to gain a better understanding of the existing industry standard around the management and decision making processed used in delivering sustainable homes. The researchers would like to receive feedback on their proposed project management theory for enhancement and adoptability.

Methods and demands on participants
If you choose to be involved in this study, you will be asked to participate in a semi-structured interview conducted by Masters student Scott Redwood. The interview will focus on your experience in commissioning a sustainable home - more specifically, your perceptions concerning the interaction between the different stakeholders (i.e. architect/designer and builder), the decision making process that was utilised (and decision justification), the overall project management , and the overall success and/or failure. The interviewer will then explain how a project is deemed to be 'sustainable' and 'successful', and critique the researchers proposed management theory based on your experience and perceptions.

The interview is expected to take about 15 min and will be audio-recorded to ensure accurate transcription. You are invited to request a copy of the transcript, and to submit edits/revisions. The information from your interview, possibly including some direct quotes, may appear in the Masters thesis of the interviewer and academic journals, subject to your consent. You will be asked if you wish to be given a pseudonym if direct quotes are used.

Being a participant is voluntary, therefore each participant has the ability to withdraw from the study up to the date of the interview. The recorded responses to questions will be issued to the relevant participant to review, alter, and accept and/or disprove. If a response from the participant is not received within 28 days, the researchers will assume approval for the documented responses to the researchers questions.

Inconveniences and discomforts
The major inconvenience will be your time spent in the interview. Your involvement in the study is voluntary, and you may withdraw your participation and any data that you have provided to that point.

The Project Organiser
This project is funded by the Sustainable Buildings Research Centre, University of Wollongong. If you have any enquiries about the project, or would like to volunteer to participate, please contact: Scott Redwood (0405 025 597; sar400@uowmail.edu.au). This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. If you have any concerns or complaints regarding the way this research has been conducted, you can contact the University of Wollongong Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Thank you for your interest in this study.

Prof Timothy McCarthy
Professor; Civil, Mining and Environmental (CME) University of Wollongong
10th June 2014

Sustainable Buildings Research Centre (SBRC), Faculty of Engineering
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PARTICIPANT INFORMATION SHEET

Project Title: *Sustainability and Our Homes*

Participant: General Public (clients with case study)

Purpose of the research
The aim of this project is to gain a better understanding of the existing industry standard around the management and decision making processed used in delivering sustainable homes. The researchers would like to receive feedback on their proposed project management theory for enhancement and adoptability.

Methods and demands on participants
If you choose to be involved in this study, you will be asked to participate in a semi-structured interview conducted by Masters student Scott Redwood, and allow sanitised information from your development to be used as a case study within the final thesis. The information gathered and used from your development for 'the case study' will include: the client brief, financials, life-cycle analysis, energy modelling, and a water analysis. The interview will focus on your experience in commissioning a sustainable home - more specifically, your perceptions concerning the interaction between the different stakeholders (i.e. architect/designer and builder), the decision making process that was utilised (and decision justification), the overall project management , and the overall success and/or failure. The interviewer will then explain how a project is deemed to be 'sustainable' and 'successful', and critique the researchers proposed management theory based on your experience and perceptions.

The interview is expected to take about 15 min and will be audio-recorded to ensure accurate transcription. You are invited to request a copy of the transcript, and to submit edits/revisions. The information from your interview, possibly including some direct quotes, may appear in the Masters thesis of the interviewer and academic journals, subject to your consent. You will be asked if you wish to be given a pseudonym if direct quotes are used.

Being a participant is voluntary, therefore each participant has the ability to withdraw from the study up to the date of the interview. The recorded information use for the case study will be sanitised of any identifiable information and issued to the participant, and responses to questions will be issued to the relevant participant to review, alter, and accept and/or disprove. If a response from the participant is not received within 28 days, the researchers will assume approval for the documented responses to the researchers questions.

Inconveniences and discomforts
The major inconvenience will be your time spent in the interview. Your involvement in the study is voluntary, and you may withdraw your participation and any data that you have provided to that point.

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APPENDIX E: INTERVIEW QUESTIONS

- Professional interviewee questions

Interview Form

Project Management Framework for Delivering Sustainable Residential Developments

The interview will be based around a number of open questions to professionals that have agreed to be interviewed.

General background on SBRC and interviewer´s activities

I am interested in how we can better manage the design and construction of sustainable domestic houses in Australia. More specifically, I believe that the shortfall in delivering sustainable homes in Australia is in the management of their execution. Through a standardised management framework and processes (a project management theory), companies will be given a foundation that will assist them in delivering more sustainable homes that are better tailored to their clients' needs.

At this stage, I would like to better understand how designers and buildings manage sustainable developments. For this context, the designer and builder is a key stakeholder, and driver of the development and therefore a critical component when managing the delivery of home. So ultimately, I am hoping to use your input in deriving the project management framework.

Questions

Overall:

- How do you classify or define 'sustainability'?
- What are the key risks for a domestic building development, and how do you successfully manage this?
- What current management techniques are being used by you to deliver successful building developments?
- How do you monitor or track the progression of a development, to ensure they are remaining on target to achieve their (your clients) objectives?
- From your point of view, what constitutes as a project failure/s and success/s (during the entire development - design, construction and commissioning)?
- Who are the key stakeholders during a residential development, and state their relationship (with one another) and significance/influence?
- From your experience, what challenges typically hinder the delivery of sustainable homes?

Social:

- How do you capture requirements and objectives from your clients?
- What method/s were used to incorporate the client into the decision making process?

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- At which level do you feel the client should be incorporated into the decision making process (i.e. high level - layout, fixtures and finishing's, or detailed - construction methods, materials and detailing?)

Financial:

- How was the budget managed during the development process (from concept design to completion)?
- How is the budget incorporated into decision making?
- What contract/s types do you prefer (e.g. cost plus, lump sum, etc)? and why?
- How do you manage cost overruns/variation, and generally what are the main reasons for variations?

Environmental:

- How do you present sustainable 'feature/s', and justify them with respect to your clients' objectives?
- How important is validation of environmental/sustainable 'features' within a development?
- Are any performance metrics use to measure the environmental impacts of your designs/construction (e.g. a percentage reduction in: energy use, embodied energy, water demand, etc)? If so, how was this validated in the final design and construction?

At the conclusion of the interview:

- Is there anything else you would like to explain about the process that you take your clients through to commission their sustainable home?
- Thank you for your time.

- Client interviewee questions

Interview Outline Form

Project Management Theory for Delivering Sustainable Residential Developments

The interview will be based around a number of open questions to the (past/present) clients that have agreed to be interviewed.

General background on SBRC and interviewer´s activities

I am interested in how we can better manage the design and construction of sustainable domestic houses in Australia.

At this stage, I would like to better understand the experiences of clients' who have commissioned sustainable homes. For this context, the client is the key stakeholder and therefore a critical component when managing the delivery of their home. So ultimately, I and hoping to use your input to help me to create a better project management practice.

Questions

Overall: In relation to your house project

- What is sustainability (How do you classify or define sustainability within domestic houses)?
- How was your development managed? Did you employ an architect or project manager?
- Was there any surprises during the development of your home?

Social:

- How were the requirements and objectives for your home gathered?
- What method/s were used to incorporate *you* into decision making process?
- How important is it to you to be a part of the 'process'?

Financial:

- How was the overall development budget managed?
- What contract/s types were used? and were they successful, limited and/or challenged?
- How were cost overruns/variations managed?

Environmental:

- How were sustainable 'feature/s' presented, justified and incorporated?
- How important is validation for environmental/sustainable features?

At the conclusion of the interview:

- Is there anything else you would like to tell me about the process that you went through to commission your sustainable home?
- Thank you for your time.

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APPENDIX F: PARTICIPANT CONSENT FORM

SBRC SUSTAINABLE BUILDINGS RESEARCH CENTRE | UNIVERSITY OF WOLLONGONG

CONSENT FORM FOR PARTICIPANTS:
Project Management Framework for Delivering Sustainable Residential Developments

You have been asked to participate in a Masters level research study conducted by Masters candidate Scott Redwood from the Sustainable Buildings Research Centre (SBRC) at the University of Wollongong. Your participation in the research involves a short interview to aid achieving the research aims and objectives. The research aims are as follows:

i. Determine the key sustainable development objectives for domestic homes;
ii. Highlight current management and decision making methods and tools used to guide projects to completion.
iii. Investigate project management best practices and suggest appraoches to best adopt and tailor into a project management theory;

Please read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- The interview is voluntary.
- You have the right to withdraw at any time or for any reason from the study.
- The interview should take about 45 minutes; you have the right not to answer any particular question if you so wish.
- Unless you give us permission to use your name, title, and/or quote you in any publications that may result from this research, the information you tell us will be completely confidential.
- This interview may be recorded for use as a reference for the researcher while proceeding with this study. If you do not grant permission, this conversation will not be recorded. You have the right to revoke recording permission and/or end the interview at any time.

I understand that my participation in this research is voluntary; I am free to withdraw from the research at any time. My withdrawal from participation will not impact my relationship with the University of Wollongong.

By ticking and signing below I am indicating my consent to:

☐ participate in an interview concerning project management and decision making methods and process relating to domestic developments.
☐ the interview being recorded by the researcher for later transcription and analysis.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

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(Please check all that apply)

I allow for the following information to be included in publications resulting from this study:

☐ my name ☐ my title ☐ direct quotes from this interview

..../........./..........

Signed Date

....

Name (please print)

Please contact Scott Redwood (0405 025 597, sar400@uowmail.edu.au) or Timothy McCarthy (02 4221-4591; tmccarthy@uow.edu.au) with any questions or concerns. If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on 4221 3386 or email rso-ethics@uow.edu.au.

APPENDIX G: INTERVIEWERS REPORTS

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Architect 1
Interview Date:	15 August 2014
Interview Location:	Architects Office (meeting room)
Duration:	49 minutes

Interview Responses

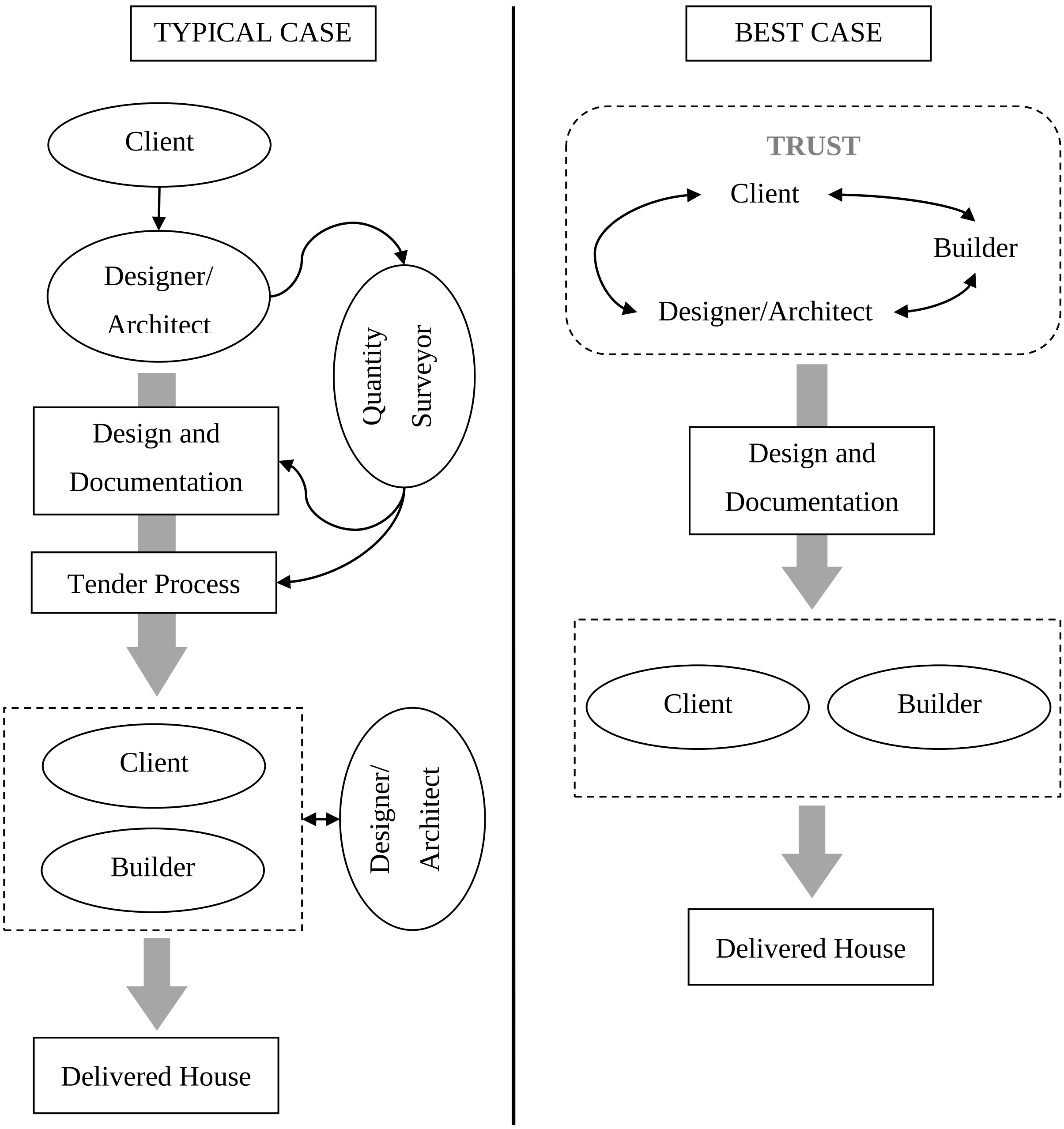
OVERALL

- Sustainability, what is it and how do you define it? Sustainability for houses focuses on meeting the needs of a client, socially and financially. Environmentally, the focus is on a passive design and material selection. BASIX is the only methods used to confirm validity and compliance for the house performance.

- Managing project risk. There were four main project risks identified, they are: managing of project cost, accurately capturing client requirements (to create the brief), meeting client expectations (achieving the brief) and delivering the project (construction). Project cost is controlled by engaging suitable professionals (e.g. quantity surveyors), domestic builders are also engaged during the concept stage, although it is noted that they generally are less effective at predicting final construction cost at the design concept stage. The quantity surveyor bridges the gap during design concept and detailed design, when the domestic builders quote for the project. Capturing client requirements and desirers is managed by an initial meeting and a comprehensive open and closed checklist/questionnaire. At this stage, only social function and form and financial requirements are gathered. To consider more environmental design objectives (other than BASIX), an additional cost is outlined. Meeting expectations outlined in the brief is achieve in a similar manner as controlling client variations. All design decisions and proposed variations are referred back to the design brief. It was emphasised the importance of relating each design decision, and direction for the project back to the past decision and to the design brief. Allowing the design to evolve (to build on information/decision), and not merely 'change' without direction. Delivering the project, construction risk is managed by an internal process. It entails a tender process - with uniform proformas, and detailed documentation. Provisional sums are considered and unit rates confirmed.

- A project failure. An overall project failure is an unsatisfied client, in terms of their social requirements and financial budget. At the end of a project, the overall success of a project is determined by external parties conducting interview and questionnaires with clients - this only covers aspects of their initial brief, i.e. only social and financial factors. Partial project failures are not specifically considered, only the overall satisfaction of the commissioning client.

- Stakeholder management was discuss in terms of a flowchart during the life of a project. Two flowcharts were scripted to describe the design and construction process, a 'typical case' and a 'best case' flowchart - which is suggested to be an optimised solution. It was expressed that the typical case evolved through the conditioned nature of business, legislation, litigation and compliance protocols (development approval processes) - but in most instances, hinders the delivery of more successful houses. For both instances, the aim is to enhance communication between the stakeholders. It was expressed that this could be more effective in the proposed 'Best Case' flowchart. The three main stakeholders, the client, architect/building designer and builder are involved at the commencement/commissioning of the project. This would allow for a more accepted and holistic client brief, and each key stakeholder has a complete understanding, input, ownership and can add their knowledge and experience to ensure an achievable client brief.



SOCIAL
• A high emphasis is placed on the client brief, it was expressed that the client brief is the most important document to guide the project. Determining the objectives/content of the client brief is completed via a proforma which details the social and financial requirements of the client. This proforma is then discussed at the initial meetings to 'flesh' out exacting requirements. The client brief is then agreed upon by the client and architect. • The decision-making protocol during the design and construction process is ad hoc, and depended on the client. The approach is 'tailored' to the client, to suit the natural temperament of a working relationship. The level of decision-making input is also gauged by this relationship, and managed accordingly.
FINANCIAL
• It was expressed that 'lump sum' or fixed price contracts are preferred. This mitigates financial risk for project overruns, and focuses key decisions back to cost - therefore helping to manage key objectives. • Cost overruns are managed within a fixed price contract by 'Provisional Sums'. A provisional sum is an allowance within the fixed price contract for work to be completed. Generally, a provisional sum is used because an accurate costing could not be determined at the onset of construction (for example, excavation of rock). A provisional sum could be considered similar to a 'cost-plus' contract, but only for specific work activities within a fixed price contract, i.e. excavation of rock, it is unsure the amount of time and work it will take to excavate, an allowance (provisional sum) of '$5,000' has been placed within the fixed price contract, but final excavation of rock cost will be issued to the client (plus builders margins). Through experience, the '$5,000' is estimated, but the builder and subcontracts take no responsibility. • Cost variations, to initial budget and fixed price contract are not considered as cost overruns, but as 'extras'. They are considered as extras as they are at the request/approval of the client, and not due to the inactions of the designer/builder.
ENVIRONMENTAL
• Currently, the interviewee and firm are on a 'learning curve' and up skilling their staff in environmental techniques, technologies, methodologies, materials and approaches. Traditionally, they only considered building orientation and passive solar design as their basis for their designs. • It was expressed that there is no demand for further analysis of environmental performance, therefore leaving the validation in the custody of the designer/architect. Holistically, validation is considered important, but currently not considered with respect to environmental measures within their building designs.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Building Designer 1
Interview Date:	7 August 2014
Interview Location:	Sustainable Building Research Centre (SBRC), UOW (meeting room)
Duration:	1 hour 9 minutes

Interview Responses

OVERALL

- Sustainability, what is it and how do you define it? It is a word which the value of which has been demeaned over the years. Generally, consumers only associate technical terms like energy efficiency and water tanks to sustainability, not the wider context. Where builders only pay 'lip-service' to the notion, as it has a connotation to disrupting their 'norm', which creates a perceived difficulty and added risk. Tangible, and foreseeable low risk options are only proposed by builders, i.e. waste management, site environmental management and tree protection. The building designer states that in their workplace, they have a higher understanding on sustainability. They consider long term consequences, include cost, to reduce total project impact. They seek the 'easy gains' for building performance and where are the necessary ones, often these are aligned.

- Managing project risk. The greatest project risks are described as not achieving initial project objectives and sustainable outcomes that are outlined in the client brief. This risk primarily stems from prioritising other perceived gains over sustainable outcomes. e.g. from budget constraints, sacrifice grey water treatment and retain the granite bench top. In addition, the level of education or knowledge of sustainability pertaining to homes is a risk, from the direct clients and their extended relations. This risk is based on the influence of non-expert advisers on clients decisions. The project risks are best managed through education and communication. Continual client engagement and involvement, coupled with a 'stepping-stone' program of sustainable housing education helps mitigate this risk, by keeping the client continually updated with design, decisions made, their holistic implications, and the value of each decision to achieving overall project objectives. The educational approach by the building designer must take into account the clients level of knowledge, and use this as a base starting point.

- Planning stage is an unavoidable risk, either Development Application or Complying Development. It is felt that most planning documents are written with good intent, but the risk is apparent in the administering and governing the planning documents. Personal agendas by the administering town planner can come into play, which are unavoidable for any project DA submission. In addition, within the NSW housing code, 'blunt objects' hinder 'general rule' sustainability, i.e. solar access, orientation and passive design. For example, the planning process relies on BASIX to measure a houses level of form and sustainability merits. Due to its innate nature, will never

bring a sustainable solution to the building industry.

- A project failure. For the perspective of the interviewee, a total project failure is if the project doesn't take place, the building is never commissioned. It was explained that this outcomes generally occurs because of budgetary issues, which stems from not understanding the budget at the initial design brief and considering this hard-constraint during the design concept and detailed design stages. Partial failures are the most common failures within projects, and generally entail the commissioned building 'falling-short' on initial sustainability performance and building performance targets. It is explained that generally, short falls in targeted performances propagate from detail and material changes made by the client and/or builder and errors during the commissioning of the building. This failure, or project risk, is managed by more detailed documentation, which ensures 'shuffles' accountability to the builder and client. The most effective solution is having more control, and being involved in the delivery of the project, so compliance can be more effectively managed.. cify to, prevent it from happening. It still happens but you have the documentation. It might be the clients failure.

- Stakeholder management was not specifically discussed, the discussion focus shifted more heavily towards managing sustainable objectives with client requirements. However, connects can be drawn between the interaction of the key stakeholders. The designer expressed the importance of a high level engagement with the commissioning stakeholder (the client), and keeping up to date with the legislative requirements to better control the development application process. Building/Designer stakeholder interaction depended greatly on the type of contractual requirements set out by the building commissioner.

- Typical hindrances to delivering sustainable homes. The government regulator, the development approval process is wrong in terms connecting good, passive and functional design which is approvable (within LEP and DCP) to the planning officers personality, approach, thoughts and influence on the understanding of the governing development documents. For example, planners 'miss it', they concentrate on probity and process rather than issues of sustainability, and achieve the most 'appropriate' outcome. Another hindrance for sustainability is education. This is representative across all facets for the housing market from building designers/architects, clients, council and government bodies, general public, builders, and real estate agents. The level in education regarding sustainability across the varied profession lend itself to a segregated approach and understanding to delivering a 'sustainable home' and buildings. The education for sustainability needs to be holistic, and embodied within our nature of doing business.

SOCIAL

- Capturing the requirements of the client and their objectives. The building commissioning process starts with the design brief, this brief must capture objectives at high level. For example, it must contain person requirements for the buildings usable space, but also the projects constraints (e.g. land conditions and limitation, DCP conditions and client budget), and design performance criteria (e.g. energy performance, recycling and water reuse). To accurately capture and define the client

brief, clients are encouraged to do some preliminary reading, for example 'Your Home Technical Manual' (especially the sections on passive design and the introduction chapters on energy and water). This method begins the 'education process' for the client, and eventually helps them understand exactly why and how their house was design and constructed in its final form. It also gives them an inner understanding of how the building functions.
FINANCIAL
• The budget is a major player in the design and construction of a house, and has to be addressed at the first meeting, and considered during the entire design and construction process. At the design brief stage, the target budget it set, and therefore the road map for the design and construction method, i.e. the construction approach - contracts, project home, material/construction systems and custom builders. • Generally, for a standardise method to mass design and construct sustainable houses, the current form of 'project home' and 'custom' construction needs to change. A systems approach needs to be found that is adaptable to individual client briefs, i.e. a hybrid approach between the two typical forms of house construction. Project home builders have a low grade systems approach while custom builders are never going to be widely available. • Typically, building designers/architects only design and in instances quality control the construction. The construction management is held with the client and builder. This disconnect lends itself to several project risks, for example, responsibility of the budget, control of variations, and delivery of the house to the design intent. For a standardise methods, this needs to be bridged. • It was expressed that 'lump sum' or fixed price contracts are preferred. This mitigates financial risk for project overruns, but it requires finer detail within the design and quality management with respect to the allowances within fixed price contract. Cost plus is a great method for out of the ordinary designs and the client has the financial capacity to take the risk (only applicable to a small percentage of persons). • System builders rely on know/provide construction material systems to build with, e.g. insulated formwork walls and suspended levels. The scale of a 'system build' extends from a 'project home' at one end, to fully fabricated factory built houses at the other. Both have positives and limits to achieve project objectives. • Initial cost estimates are generated by quantifying material quantities from the CAD model and unit rates. • The interviewee stated that cost overruns are typically caused by something unexpected, something that could not be identified and therefore controlled. This generally happens during renovations projects. Geotechnical and ground water uncertainty embodies most cost overruns within new construction projects. In addition, the other significant cost overrun is client changes. If not managed correctly by the responsible parties (i.e. designer, builder, client), the budget will no longer be controlled.

ENVIRONMENTAL
• Environmental feature are presented to clients and justified by demonstrating their merits and compatibility to achieving the client brief. How the environmental feature is presenting shall also be a consideration. For example, FSC timber has slightly increased cost of the construction, but discuss the point from managed forests against illegal logging. The clients 'notions' should be considered. • How important is validation. Most clients do not ask for validation. This is for two main reasons, clients typically trust the direction/advise of the designer and the added cost to produce reports. The interviewee presents validation in terms of payback period on the investment and diminishing returns, and achieving a higher than average NatHERS star rating ("eight stars is a good place to be"). • BASIX used to be used to demonstrate an exceedance of standards. Currently, BASIX is not used at all, as it has lost its impact. • An additional note, the clients notions also extend beyond financial payback. The reliability and quality of the features/home can have a higher value to the client then a quantitative 'expected' payback period.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Builder 1
Interview Date:	13 August 2014
Interview Location:	Coffee Shop, Austinmer
Duration:	58 minutes

Interview Responses
OVERALL

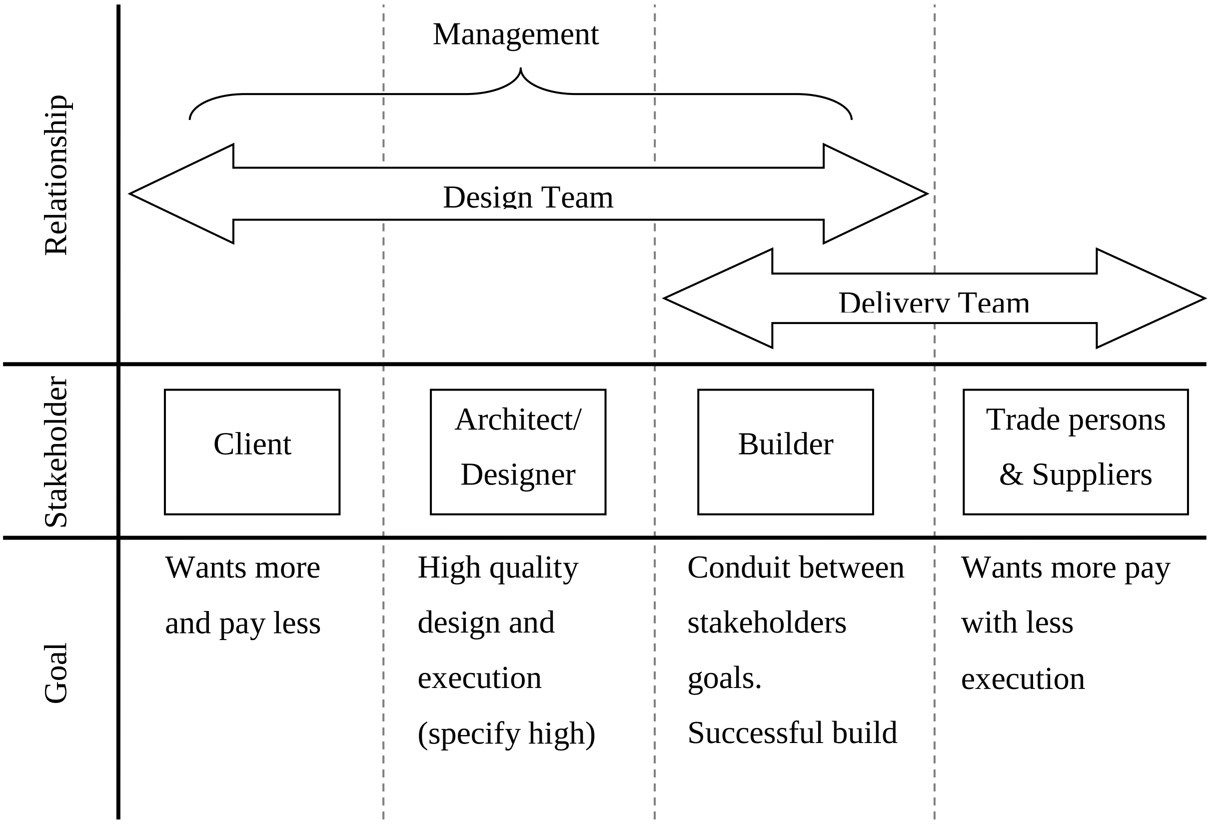
- Sustainability, what is it and how do you define it? A sustainable home is one that best encapsulates its location and the design and construction constraints. Sustainability within a home begins with ensuring a good passive solar design, and a good thermal envelop. In addition, sustainable homes must use materials that are renewable and do not complete (e.g. FSC timbers). They should also embody the use of recycled, up-cycled and reused materials. Site waste and environmental management is also a critical factor that is generally not considered during the design. Minimising waste and controlling environmental effects can also reduce construction costs.

- Managing project risk. The core risk for a project is the control of the construction budget. There is two key area of budgetary risk, they are described as expectational risk (i.e. the client expects more from their money) and design changes (either from the client or designer/architect). These project risks are controlled by this builder through clear communication, through ongoing face-to-face meetings. The communication shall entail accurate meeting minutes, and monitoring of construction progress (i.e. time, budget, procurement and quality). Typically, the budget is managed by 'dropping' off initial requirements. For example, sustainability features get reduced/changed to 'make-way' for the variations and/or additions.

- A project failure. A total project failure is determined by the clients 'happiness' at the project's completion. In addition, a successful project must be gauged by the financial profitability of each business and professional involved in the project. It is expected that each person or entity involved should make a "fair and reasonable profit". As the key stakeholder in the construction, the builder must manage this through clear communication and contracts between all associated stakeholders (e.g. subcontractors, suppliers, consultants, and the client). Sustainable outcomes are always at risk due to budgetary constraints, not achieving pre-set objectives is also a failure. It is felt that this is best managed through education to the client, and clearly expressing the benefits and knock-on effects of changes/reductions in sustainable features.

- Stakeholder management was comprehensively discussed, and how the interplay between each stakeholder occurred with difference contractual circumstances. The contracts set out the relationships and responsibilities between the 4 stakeholders: the client, architect/designer, builder and subcontractors/suppliers. A diagram was drawn

to explain the relationship between the stakeholders, and their typical specific overall goals. The diagram illustrates that the builder wears two hats, one in design and the other with delivering the design. Depending on the contract, any of the 'design' team can be ultimately responsible for the overall delivery of the project. It was noted that this method can cause conflict between the builder, and the other stakeholders because boundaries are not clearly defined and managed.



- Typical hindrances to delivering sustainable homes are the budget and time. No two designer houses are the same, in addition no two site conditions are the same. Therefore each project creates their own unique challenges. The most sustainable result is evolving with the experience of delivering sustainable homes, and with better means of educating the decision makers (client and designers) with options, materials construction methods that best suit the site constraints.

SOCIAL

- From the builders perspective, they are not involved in the development of the clients brief, this is typically prepared and given by others. Which can create conflict when trying to deliver unrealistic objectives with defined budgetary constraints. It was expressed that in recent times, clients approach the builder (the interviewee) for advice and guidance during the design process, which is felt to better balance design with expected project outcomes by providing more 'realistic' construction parameters (construction parameters area site conditions, site access, site logistics, construction process, materials, construction time and construction budget).

- Generally, there is conflict between the initial client brief (i.e. outlined constraints),

and delivering a house as per the initial design intent. The design needs to be further adapted to suit the construction parameters.
FINANCIAL
• Cost-plus contract best for innovating building, more easily allows for change, unique materials, building processes and high-quality of finishes. Key stakeholders must be involved in each decision, and cost variations expressed immediately against the 'new' anticipated total build cost - communicate the 'bottom-line'. • Fixed-price contract are best to manage cost, but need a high level of detail and communication before commencement. More time and effort must be invested during the design and contract stage. • Variations are managed by continual updates to the client, and/or designer. This typically happens every two weeks to ensure no surprises arise, especially from design changes.
ENVIRONMENTAL
• It is felt that the term 'green' and 'sustainable' is being highly overused, and only used as a marketing exercise without any validation. There are different levels of validation, for example, to validate the buildings expected performance, and validate the construction process. From the interviewees point of view, construction validation is important for several reasons. Firstly, demonstrate how effective the construction processes were, gauge the overall success of the construction period, allow to learn from captured information - refine processes/methods, and as a marketing tool. Depending on the project, the level of validation changes. Typically, the following is captured: construction speed (with respect to construction method and materials), waste management (recycled content), up-cycled/reused material within the new building, review of energy, lighting, mechanical and water systems (cost, installation, warranties, effectiveness), environmental management. There was an emphasis placed on materials, their use, maintenance, recycled content and recyclability. • It was expressed that the design and construction industry should develop 'best practice' or 'rule of thumbs' for delivering sustainable homes. With growing experience, rule of thumbs for constructing bespoke sustainable architectural homes are becoming refined (for the interviewee), but not widespread. Validation of the interviewees previous and current projects allows a 'closed-loop' for lessons learnt, and an evolving method of materials, detailing and construction processes. It is felt that a similar validation is just as important to designers and architects, higher levels of validation will evolve better 'rules of thumb' in their designs, and design details (leading to a more effective construction). • During the construction, no performance matrices are used. The interviewee has their own internal benchmarks, processes and validation methods. This is demonstrated at the interview stage, through captured validations and embedded in the presented construction cost.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Builder 2
Interview Date:	5 September 2014
Interview Location:	Builders Office
Duration:	1 hour 24 minutes

Interview Responses

OVERALL

- Sustainability, what is it and how do you define it? "It is hard to define sustainability within housing because there is so many variables associated with it." A few variables were named, they were: The materials, product systems, cost, design concept and construction waste. The builder considers sustainability within houses as a 'work in progress', which typically is controlled/governed by build cost. Build cost inevitably dictates the overall result of a project, however good management of build costs and greater knowledge on materials, waste management and construction methods facilitates for a more sustainable home. The Interviewee also communicated the evolution of construction management, construction processes and materials. New approaches/concepts/materials typically need to be proven (by others - i.e. not builders) before acceptance and adoption. Adoption by builders is a very long process, however once adopted build costs reduce. Due to the nature of the building industry, this acceptance and adoption can take decades.

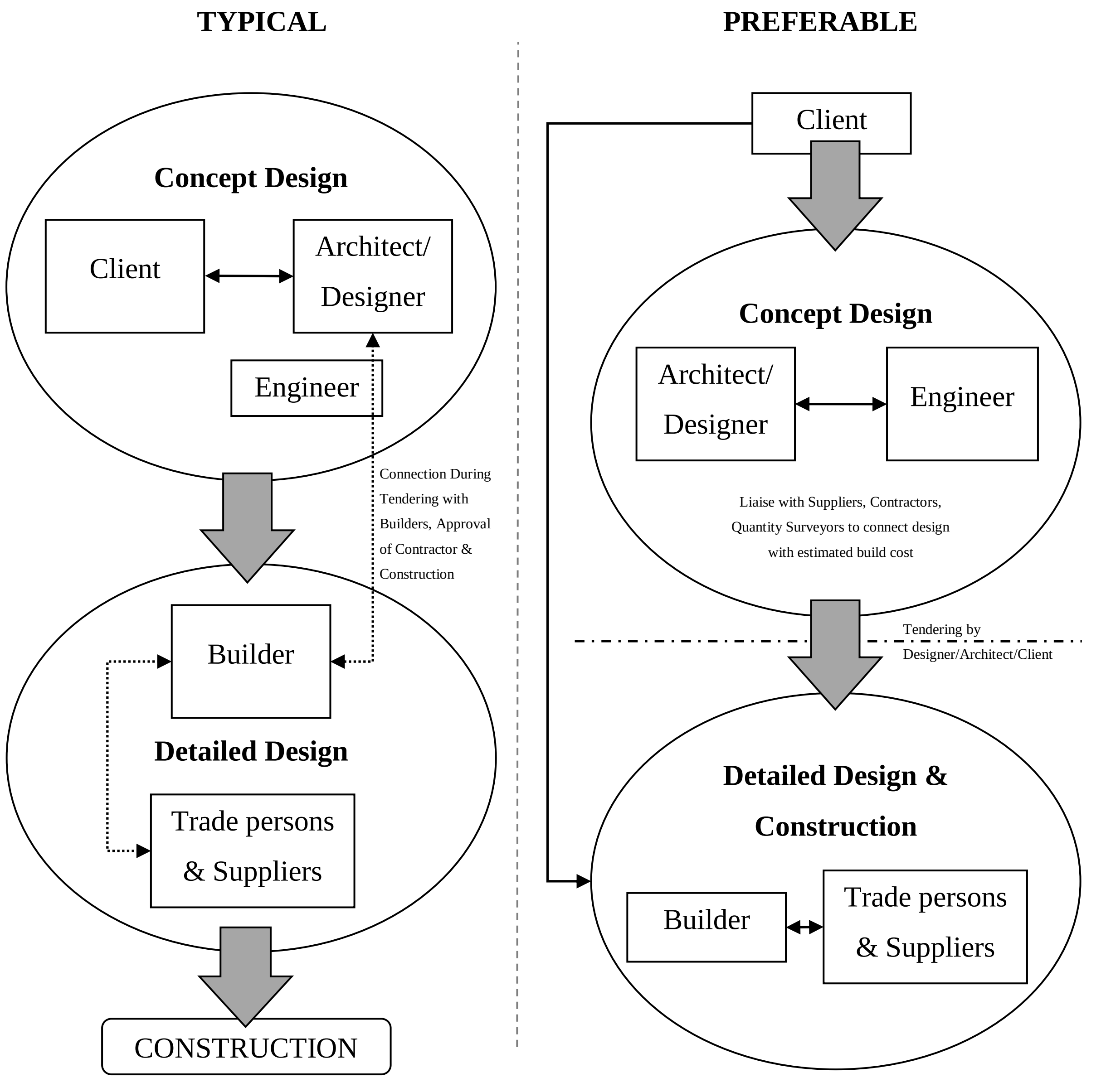
- Managing project risk. There are two (2) core project risks identified by this builder, they are: controlling the construction budget and project liabilities. Typically, this builder works to fixed-priced contracts. Therefore controlling the construction budget is critical to the project's success, but also the builders profitability. In addition ensuring the initial, signed quote is accurate and comprehensive - to not be 'caught-out'. Project liabilities is a core risk for the builder, these risks stem from: building design (constructed materials and details given by others - i.e. design consultants), 'unusual design', new materials, waterproofing, subcontractors work, environmental management, and site safety. During the project, and 7 years after the project the builder needs to warrant all aspects of the 'constructed design' - regardless if the details and material selection was by others. This builder manages this by being proactive in the project, 'attention to detail' in all aspects of the construction is critical if the construction of the home is to be successful and the successful longevity of the business.

- A project failure. For the interviewee, a total project failure is when they and/or the client is not happy at the end of the project. Note, there was no formal measure or survey mentioned to gauge overall satisfaction at the end of a project - only based on personal perceptions. To achieve an overall success for a project, the interviewee expressed the importance of clear communication and documentation between the

client, the designer and the builder. Examples of potential minor failures were presented, but not discussed by the interviewee.

- The key stakeholder interactions was comprehensively discussed, and interpreted in the form of a flowchart (both typical and preferable). The interviewee believed that the current flowchart (industry environment), from the point of view of the builder has two inherent flaws with respect to delivering an overall successful projects. Firstly, to successfully deliver a design that connects the clients essentials and desirables, project constraints (hard and soft), and the design team to the construction team (inc. construction budget). In addition, the disconnect between design, construction and construction budget is also typically experienced during construction - and championed by the architect/designer, generally placing their own 'agenda' in front of needs and constraints of the client. Secondly, the tendering and construction of the project with the construction team (i.e. the builder, suppliers and subcontractors). The current process requires accurate documentation and tendering procedures to ensure subcontractors quote accurately, and each tender price are comparable - "apples with applies". In domestic practice, it is expressed by the interviewee that the accuracy of documentation and the 'ad-hoc' nature of the tendering process instils a level of assumptions, allowances, inaccuracy in pricing, and therefore a incompatibility of tender prices.

- The proposed and preferred stakeholder structure places more responsibility on the architect/designer to validate their design decisions, material selections and even consider the construction methodology during the concept design. It was suggested that this could be done via a Quantity Surveyor, and/or liaising with suppliers, subcontractors and builders during the design stage. In addition, construction budget validation should allow architects/designers to invest more time (with confidence) in detailed documentation, for more complete documentation. The second amendment to current practice stems from the more complete documentation. For typical building projects, this will allow the building contractor to be more hand-on with the client, and work with them one-on-one to deliver the accurately documented house. With the original architect/designer only involved when necessary - and not championing this stage of the project.



- Typical hindrances to delivering sustainable homes are the budget and time. No two designer houses are the same, in addition no two site conditions are the same. Therefore each project creates their own unique challenges. The budget can create opportunities for the development (if the key stakeholders are invested in sustainability and material conservation), it allows for a greater emphasis to be placed on the design, materials, and evaluating performances.

SOCIAL

- Typically, the builder is not involved in the project when the project objectives are derived. The interviewee explains that this can create conflict, especially when the clients 'hard constraints' were not adequately considered during the design process. Generally, this refers to a miss-match in designer construction budget estimates and builder quotations, but this can also refer to constructability of the building concept.

• The interviewee explains that they are typically engaged during the house is waiting for or has DA approvals. At this time, the interviewee has no 'formal' method of capturing client objectives, but merely response to the documented design and the clients budgetary constraints. • Throughout the interviewees management practice, they ensure the client is involved in every decision, at every level to make sure the client had ownership of their the project decisions - especially with the budget, and knock-on changes to the design.
FINANCIAL
• Generally, the interviewee works with 'Fixed-Price' contracts. This is due to the nature of the works undertaken by the interviewee - i.e. project difficulty and the client's financial capacity. From the beginning, a 'Fixed-Price' is develop in conjunction with the Client, and where requested (by the Client) the architect/designer. This is developed by breaking the project down into each trade, and obtaining construction quotes. It is noted that this process is depended on the quality of the documentation, and communication between the builder and subcontractor to 'how' the house will be constructed - as this is directly related to how each subcontractor organises their quotes. • Changes during construction are not considered as variations, a variation is rare and is only encountered when a work-action could not be anticipated during the tendering stage. Typically, budget 'overruns' are due to documented design changes - either before or after the works have been completed. • Fixed-price contract are best suited when a design is 'pushing the boundaries', and the client has the financial 'freedom' to place build quality above build cost. This scenario is much less common to the typical, 'Fixed-Price' financial conservative approach.
ENVIRONMENTAL
• The interviewee considers environmental features viable, and successfully adopted by the client when they can be examined against a 'Pay-Off Period'. • It was expressed that other environmental practices are becoming common due to the nature of construction costs. For example, construction waste is inherently being separated and recycled because it is cheaper for the builder. • The user of the home can impact the usage of the house. The interviewee states that the client (potential home-user) should be educated on the products and systems being installed. For example, a gas hot water system ignites every time a mixer tap is used, regardless of the duration of use and temperature of the mixture setting. • The interviewee stated that validation is important as an industry, to continually develop products, methods and systems. But personally, the interviewee feels it is less important, and tried to keep build costs as low as possible.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Client 1 (case study)
Interview Date:	8 September 2014
Interview Location:	Cafe
Duration:	41 minutes

Interview Responses

OVERALL

- For this client, sustainable within housing is more than just environmental considerations - it is only one (1) factor. It also encompasses a place that the client wants to live in, grow in, is relatively maintenance free, low running demands and is a balance of their requirements and constraints.

- The idea, and decision to design and build stemmed from a decision process prior to looking for available land and designer/project manager. For personal and conditional reasons, this path was an option and inevitably chosen by the Client. The concept of designing and building a house has always been a desire, however the Client wanted to be more involved and create something specific to them (personal details) and the considerate to the unique block of land. For this project, the block of land is a 'difficult' aspect for the design and construction, and needed specific attention and experience.

- The Client engaged a 'sustainable' building designer and project manager to design, document and mange their project. The designer was engaged because they had experience in commercial construction. This background helped build trust in the professional to delivery their requirements on such a unique block of land. In addition, this approach suited the Clients needs to be more involved in the process, with flexibility in the outcome. Other methods were considered, they were 'Project Home' builders, and architects. Project home builders were not applicable for two (2) reasons. Firstly the nature of the block of land (steep, rocky and highly reactive clays), and secondly the limited involvement and control the Client had on the design. The architect approach relied more heavily on the Client to research and validate sustainable feature, tender the project, and manage the construction of the home.

- The key surprise during the design and construction process was associated with the project cost. The initial construction cost that was put forward during concept design stage was not effectively updated and related throughout design changes - and design documentation. This can be partly attributed to the building designer/project manager, as this is their first introduction (from commercial) to the domestic design and construction market.

SOCIAL
• The requirements and objective for this Client was initially conducted via a 'dumping of ideas' from online 'scrapbooking' websites - i.e. Houzz & Pinterest. In addition, a pro-forma was used to collect social, financial and environmental essentials and desires. In this case, the client felt a lack of connection between the decisions being made, the initial data collection and their involvement. • The Client expressed that a greater connection between the outlined social, financial and environmental essentials and desires and the decision-making process during the concept and details design in important. To make this more effective, the client suggested more validity/accuracy is required with respect to the information to allow them to make more informed decisions, with the designer/architect.
FINANCIAL
• The project cost was managed by establishing an initial project forecast budget - a breakdown of all expected fees associated with completion of the home. The Client explained that they felt that this was a good approach, however, the Client feels that this budget needed to be continually scrutinised with the ongoing development of the design. • The contract used was a 'Fixed-Price' contract, this contract type was chosen to better manage the construction cost. The process to develop the fixed price contract was more lengthy, and required more detail within the building design documentation. This also, ensured no variations during the construction of the project. • Project overruns or variations were managed by ensuring a high level of detail in the documentation. The Designer documented a high level of detail within the documentation, that ensured the fixed-price contract was tendered consistently, and the fixed prices for the build were comprehensive before commencing.
ENVIRONMENTAL
• During the design process, sustainability/environmental was not presented as standalone 'features'. but more as a set of 'targets'. For example, increasing energy efficiency (as much as possible) - demand & supply, and water conservation were considered as targets (performance indicators). Decisions were continually made, and adjusted, to produce an 'evolved' solution to best achieve these targets. It was expressed by the Client that they felt this approach instilled a conscious thought process, and justification for each decisions made - throughout the design of the home. • The client expressed that validation is very important because it justifies the capital investment - if it cannot be justified, 'why invest?'.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Client 2 (case study)
Interview Date:	4 September 2014
Interview Location:	Client's Home
Duration:	57 minutes

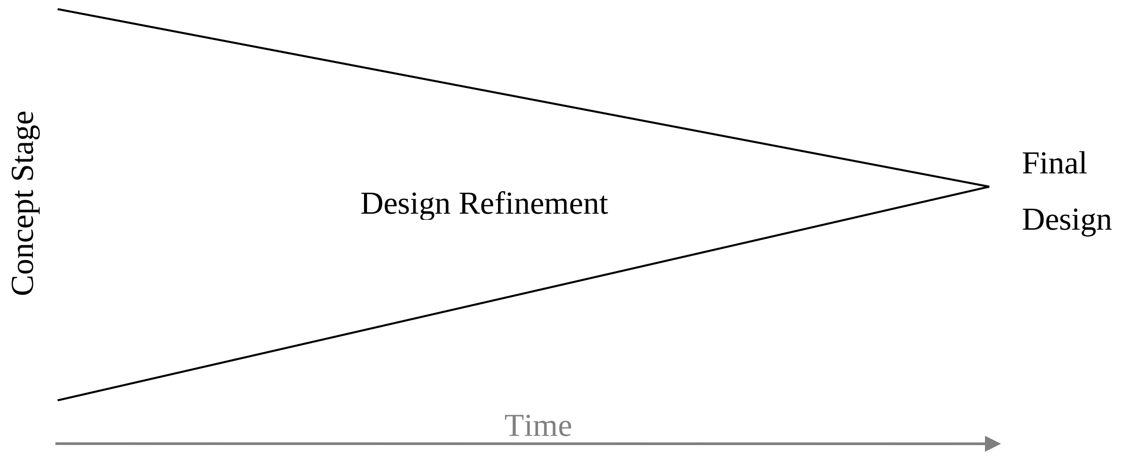
Interview Responses

OVERALL

- A sustainable home starts with the liveability and 'future proof' of the house. It must function, perform and cater for a changing life-style and makeup of the family. Secondly, it needs to have the 'basics' covered - this means a building form that takes advantage of orientation, prevailing winds and the sun. Thirdly, the building must operate as efficiently as possible and built from environmentally friendly materials (renewable and recyclable).

- From this clients perspective, the end result needs to function with their changing life-styles, not just for the now, but also as the family matures.

- The main surprise during the process is the continually changing design, a result of attempting to evolve the concept design to suit the core needs of the project, and hard/firm constraints.



- The process, and final decision to design and build begun with the idea to move into an existing home, and renovate the house to tailor it to the families needs. This was abandoned for economic reasons and personal desire to build a new home, custom to their needs. The client discussed different methods to deliver their sustainable home. The decision to employ a 'sustainability' building designer and project manager was a result of risk mitigating and reducing design costs (with respect to interviewed architects) - experience in delivering sustainable projects.

• An observation by the client, in addition to the listed questions. They felt that a more effective method to understand the clients experience, knowledge and background would help the professional 'ask the right questions'. This would more effectively 'flesh-out' the initial requirements. In addition, during the requirements collection stage, the engaged professional should 'paint' a greater picture of what is to be expected during the entire process, throughout design, compliance and approvals and construction.
SOCIAL
• The process started with engaging a 'Building Designer', who specialised in sustainable building design. The requirements for the project were collected with the means of a client brief 'pro-forma' (form, spaces, budget, uses), and the use of 'Houzz' [houzz.com.au]. Relating the interconnectedness of the initial requirements was difficult - social requirements, expected build cost, thermal performance, energy efficiency, water treatment, materials/finishes, local government requirements and site conditions. • In reflection, marrying the initial requirements during the design process gave clarity to what is important in the design, and define and refine how the spaces will be used. • For the client, it was very important to a part of the decision-making process. The client already had past knowledge in sustainability, and therefore wanted to be involved in the design process. How each decision plays on other decisions, not just in initial form/construction, but overall life-cycle of the building and its operation.
FINANCIAL
• The total build budget was outlined at the concept stage of the project. This budget has been related, via sub-budget sums (for each trade package), back to a total estimated construction cost. The design process was 'loosely' governed by expected trade package costs. • The construction will be completed via a fixed-price contract. We wanted a fixed priced contract to help manage, or reduce the risk of the cost during the construction process. The design is currently out for tender, the final fixed priced construction build is pending.
ENVIRONMENTAL
• Initially, material performances, building form, glazing, systems and technologies were discussed and 'temporary' approval was given to progress the iterative process of design. The final validation is waiting to be issued, and is expected to be issued upon an 'as-built' home. • Validating environmental, sustainable and efficiency was considered very important. If a claim, or goal is specified by the given professional they should achieve this, and prove through validation. This is felt to be part of the 'package' for engage such a professional.

- An additional aspect that was raised is the compliance (of installation), warranties and liability of materials and systems being used. It is felt that this is key contributor to the decision-making process, and should be addressed.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Client 3
Interview Date:	4 September 2014
Interview Location:	Home Office
Duration:	1 hour 32 minutes

Interview Responses

OVERALL

- The concept, or definition of sustainability evolved from the need to have a more comfortable and more efficient home. From their experience from past renovation projects, and before engaging any outside professionals, the client started their own research into sustainable housing. The three (3) core aspects for sustainability are: thermal comfort (internal air quality, natural ventilation, passive design and heating & cooling), material selection (recyclable, renewable resources, performance, maintenance and local - as much as possible), and 'Future Proofing' (the form and function of the house can adapt to their changing life styles).

- The education process begun with reviewing books, sustainable houses magazines and case-studies (e.g. 'Josh's House').

- The Client approached the commissioning of their sustainable home in two stages, firstly, getting to most appropriate design to suit their needs (including the cost of the design and documentation), and constructing the house within their social and financial constraints (the clients available time - to oversee/manage, and financial capacity). In appointing a consultant for design, the client concluded on a 'sustainable' building designer, they suiting the clients requirement because of their reduced fees (compared to an Architect firm) and can add 'finesse' (compared to a drafts person) to their already grounded house concepts.

- The initial approach to the construct the home was to 'home-owner build'. This approach was abandoned because client realised the level of expertise required and the demands this approach would have on their time.

- Surprises in the process. The two main surprises were:
    1. Matching the estimated budget (from the designer) to builders construction quotes.
    2. Managing the rebellion from building contractors against constructing/incorporating the sustainable features proposed by the design (e.g. triple glazed windows and phase change materials).

- The above surprises have led to notable design changes (shrinkage of total floor area and a different foundation design). In addition, it led to a delay the process between DA consent received to the commencement of construction. This delay is estimated to be approximately 5 months.

• Overall, the client felt the most important aspect of the design process is trust, instilling trust in the designers ability to deliver what they want/expect - especially with the environmental features.
SOCIAL
• The process started with engaging a 'Building Designer', who specialised in sustainable building design. The Designer collected five (4) core project objectives, they are: 5. Overall project goals (inc. financial) 6. Liveability goals (how and where they currently live - including flora and fauna, and how this home will compliment and add to the changing lives) 7. Sustainable goals (materials, water efficiencies, electrical efficiencies - typically qualified, quantifying goals and validation could have been requested) 8. Site and local government constraints. • For the client, it was very important to a part of the decision-making process. To understand and link their prior learning to the design and decision-making process. This endeavour was a life-changing undertaking, so commanding this was very important, especially with the 'knock-on' effects of the decisions. How each decision plays on other decisions, not just in initial form/construction, but overall life-cycle of the building and its operation. • In hindsight, the client feels that this process cannot be 'typical', because of the rigid nature of the industry. It currently requires 'champions' to push the 'envelope' and drive the delivery of a 'sustainable' home - one home at a time.
FINANCIAL
• The financial constraints were expressed and captured within the client brief by the building designer. The circumstances of the client relating to this constraint was to place an emphasis on comfort and liveability, and sacrifice internal finishes and furnishings. • The building designer managed the cost by applying a holistic square meter unit rates (i.e. $#,###.00 / sqm to construct fully-finished house). During the management of expected construction costs, there was no justification for applied unit rates, nor a connection to proposed features with cost. With relation to the first noted surprises, the fixed-price construction quotes received by builders were approximately 50% greater than the building designers estimates. It is felt that a greater emphasis should be placed on budget estimates, and a more effective connection between cost estimates, justifications of features and the decision-making process. • The client preferred a fixed-price contract over a cost plus contract. This is because their need for budget control is more important than their desire for a 'premium' finish. They faced difficulties finding the 'right' builder to suit their direction - a 'midway' point between a premium builder (typically cost-plus) and a project home builder.

• To bring the cost of the project in alignment with the financial constraints, the design of the project changed (reduced in size - retaining the same form and setout), and the foundation construction altered. In addition, key features (e.g. solar panels, driveway, etc...) have not been included in the main building contract, but can be added by the client at a later time.
ENVIRONMENTAL
• Each features that was presented came with a level of knowledge and understanding of how it integrated into the building - to work as an 'engineered' product. This also lead to an understanding of how to operate the home. This level of knowledge and understanding needs more education on the clients behalf to best aid in the decision-making process. • The features were presented and justified in a qualitative method. Quantitative analysis and validation were not presented to the client, but assumed to be conducted to support designers stance for the proposed features. Linking this back to cost would have helped the decision-making process for the client. • Translating the features to builders was fronted with difficulty. A builder that is working with the client has assisted the process. Like the designer, a high level of trust is being placed with the builder to deliver their objectives. • The client feels that typically, general people commissioning homes are not as engaging/immersed in achieve the environmental objectives of their project, and tend to be more conservative and traditional with respect to their expectations.

Interview Details	
Interviewer:	Scott Redwood
Interviewee:	Client 4
Interview Date:	11 September 2014
Interview Location:	Client's Home Office
Duration:	31 minutes

Interview Responses

OVERALL

- The core concept of sustainability for this client is material conservation. Building homes that are comfortable from materials that can be locally sourced, renewable and not harmful to the environment and human health. Secondly, the home must be efficient to own and operate.

- To date, project has been managed by the client. Before engaging a design professional, the client defined the scope and building form of what they wanted - modest straw bale house. The client engaged a building designer that expressed experience in straw bale house design, which was accepted by local council planning.

- A project manager was contacted to discuss the project upon DA approval. The construction of the project was initially going to be managed by a project manager and local builders. At this point, the project was halted for three reasons, they are:
    1. The construction budget issued during the design was greatly underestimated, and therefore financially unachievable.
    2. Difficulties in sourcing tradespersons who have the required experience in straw bale construction and rendering techniques.
    3. The documented design contained no details or consideration of constructability of the straw bales, and was determined 'un-buildable' in its current form.

- The project has needed the client to be more hands-on if they are to achieve their desired result - matching their social needs using a 'unique' building product with their allocated budget. In addition, during the process, the client has needed to become pseudo professionals in straw bale design and construction.

SOCIAL

- The building designer was specified because of their previously experience with straw bale house design. The Client have the designer 'free reign' to develop the concept, trusting their artistic direction for the project.

- No specific method/s were identifiable to the Client for the collection of personal requirements and constraints. This seemingly missing aspect of the process did not produce a final design deliverable that suited their needs or constraints.

• The Client expresses that a more hands-on approach is required to ensure the design evolves to a workable outcome. This requires a more comprehensive capturing of their requirements, vision and constrains. In addition, an effective way of guiding the design towards the most desirable outcome.
FINANCIAL
• The project budget was set (design fees and construction fees), and communicated to the designer. The design and documentation was completed, but the result was a design that did not consider the Client's construction budget. • The Client's modest budget required the project to stop when the financial constraint was not considered in the delivered design. The Client has now taken control of the design and construction of the entire project to ensure their budget is maintained. • Project cost will be managed by breaking the project down into smaller deliverables to match their budget. This will lead to a slower construction, but a successful final result.
ENVIRONMENTAL
• Typically, the sustainable features for this project/design were given by the client, to therefore be incorporated by the designer. The Client in this case used their own 'rules of thumb' which they collated via their own research. The Client also had additional requirements/specifications for the designer to include (and expressed that the concept stage), e.g. a building envelope that embodies a passive design and would complement/take advantage of the straw bales. • The sustainable features were not validated as they were incorporated at the request of the Client. This also left 'holes' in the design, i.e. the highly insulated straw bales were complimented with conventional BCA requirements for glazing, roof insulation and none-straw bale walls. • The pursuit to make a sustainable home for this Client has led to an up-skilling of the Client knowledge and skill, greater time demands for the Client and a longer overall project timeline.

Appendices H-K removed due to Copyright Restrictions

APPENDIX L: CASE STUDY A - LIFE CYCLE ANALYSIS

Life Cycle Assessment

Tree House (As-Built)

Assessed by : Scott Redwood

Certified by : Fei Ngeow

31 March 2015

Executive Summary

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

- A business as usual or benchmark design, "International Benchmark International Residential Benchmark Weighted x10 dwellings"
- Base case design, "Tree House Tree House (As-Built)"
- Improved design with modeled recommendations, "Tree House Tree House (BCA)"

Design life is a critical factor in LCAs of construction works. In this case, the estimated design life of the benchmark is 63 years and the maximum durability is 150 years. The estimated design life for the subject building "Tree House Tree House (As-Built)" is 90 years whilst the maximum durability is 100 years.

The Global Warming impact associated with the base case design totalled 203,777 kg CO2-eq

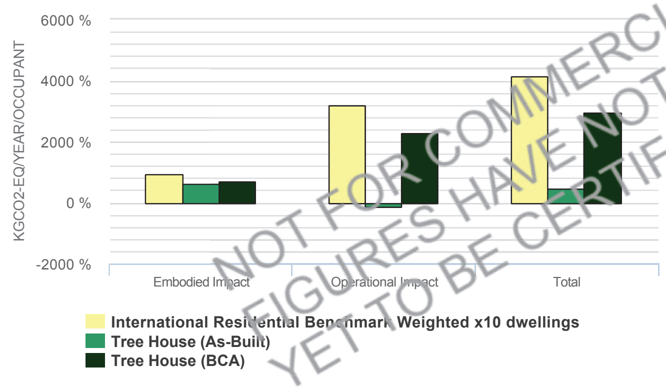
Taking into account the functional units of the building, this is equivalent to 453 kgCO2-eq/year/Occupant. This represents a 89% saving compared to the benchmark.

With recommendations a saving of 28% can be achieved.

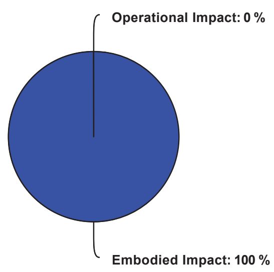
The following charts provide some further information regarding the comparative impacts of the three designs. A comparison has also been provided of the largest embodied and operational impacts. The detailed percentage split of impacts sources relating to the base case design have also been provided.

Total Life Cycle Global Warming

Comparison of Global Warming Profiles:

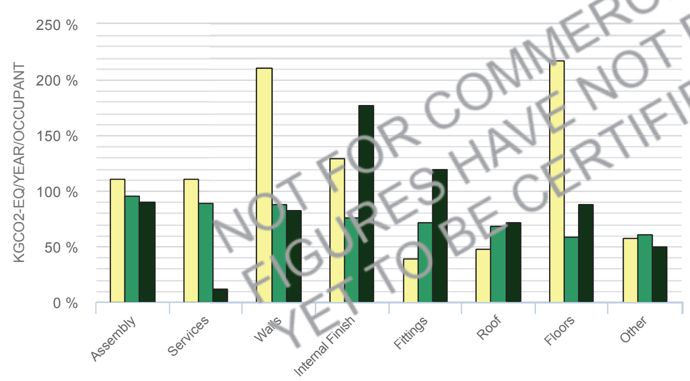


Total Global Warming Profile for Tree House (As-Built)



Embodied Global Warming

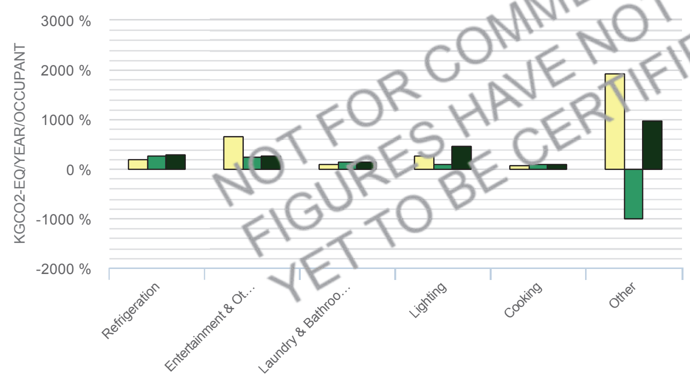
Comparison of Embodied Global Warming:



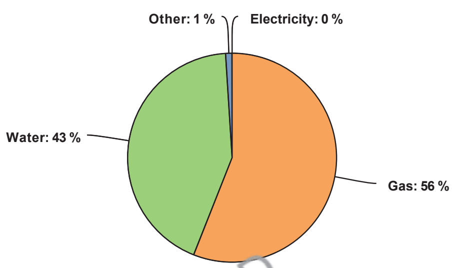
Embodied Global Warming Profile for Tree House (As-Built)

Operational Global Warming

Comparison of Operational Global Warming:



Operational Global Warming Profile for Tree House (As-Built)



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 construction works, the total life cycle energy consumption is made up of two elements:

- 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 construction works
- 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 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 construction works, this will usually be overshadowed by the influence of occupant behavior on operational impacts, or the actual construction work 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
- Inflation of construction 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 structure which can be reported on separately. Please contact us for more information.

NOT FOR COMMERCIAL USE: FIGURES HAVE NOT BEEN VALIDATED YET TO BE CERTIFIED

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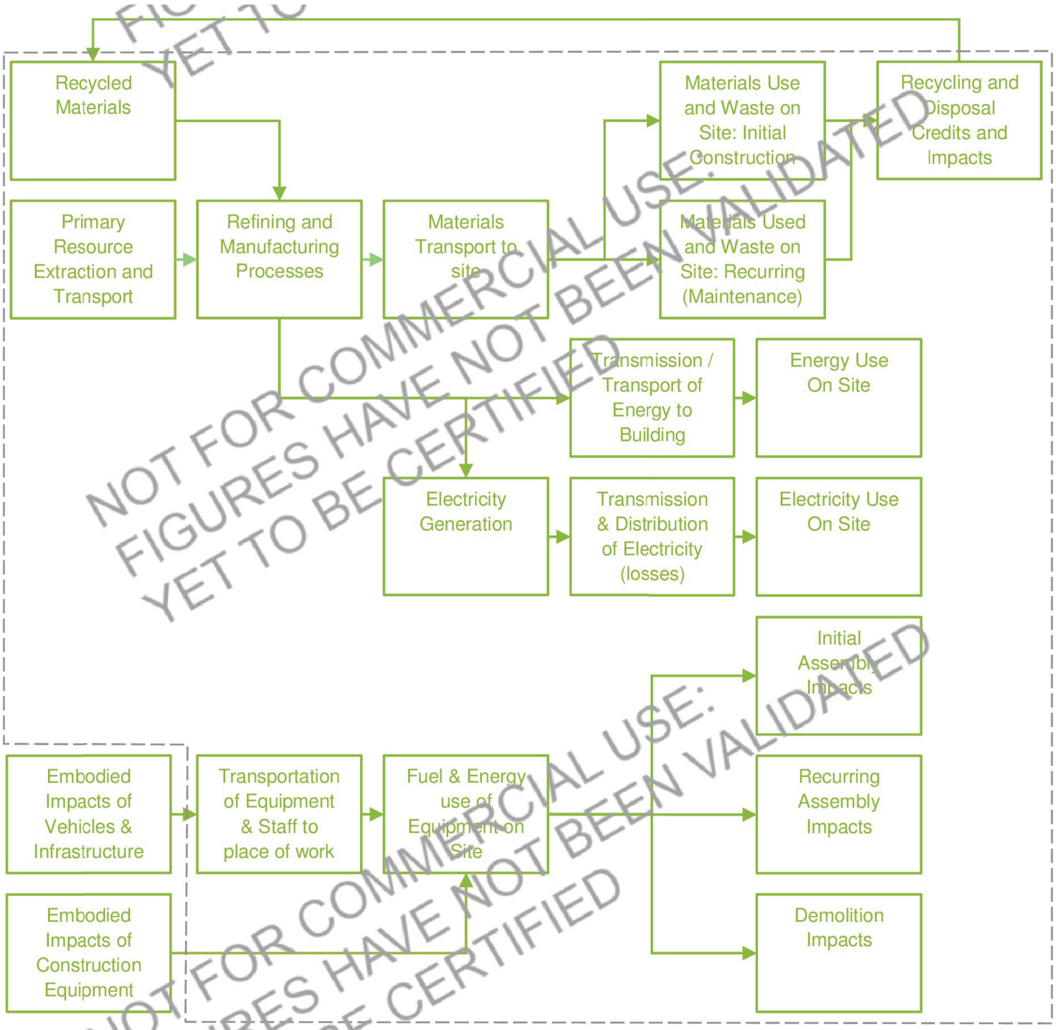

Figure 1: System Boundary of LCA

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 for each of the designs assessed is outlined below:

- Tree House (As-Built): 203,777 kg CO2-eq
- International Residential Benchmark Weighted x10 dwellings: 6,392,873 kg CO2-eq
- Tree House (BCA): 740,406 kg CO2-eq

NOT FOR COMMERCIAL USE: FIGURES HAVE NOT BEEN VALIDATED YET TO BE CERTIFIED

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 63 years whilst the maximum durability of the building is 150 years. The estimated design life for the subject building "Tree House Tree House (As-Built)" is 90 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.

Sensitivity

Estimating impacts to high levels of confidence requires costly resources, and in the case of construction works, 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.
Department of Climate Change and Energy, National Greenhouse Account Factors, Australia Government, 2011.
Department of the Environment, Water, Heritage and the Arts, Baseline Energy Estimates 1990 – 2020, Australian Government, Canberra. 2008.
Dynamics of Carbon Stocks in Timber in Australian Residential Housing, The Universtiy of Melbourne and NSW Department of Primary Industries, Forest and Wood Products Australia, 2009.
Energetics, Think Brick Australia - LCA of Brick Products, Energetics PTY LTD, 2010.
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
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US Energy Energy Information Administration, Annual Energy Outlook 2011, US Department of Environment & US Energy Information Administration, Washington. 2011.

APPENDIX M: CASE STUDY B - LIFE CYCLE ANALYSIS

Life Cycle Assessment

Escarpment View (As-Built)

Assessed by : Scott Redwood

Certified by : Fei Ngeow

10 February 2015

Executive Summary

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

- A business as usual or benchmark design, "International Benchmark International Residential Benchmark Weighted x10 dwellings"
- Base case design, "Escarpment View Escarpment View (As-Built)"
- Improved design with modeled recommendations, "Escarpment View Escarpment View (BCA)"

Design life is a critical factor in LCAs of construction works. In this case, the estimated design life of the benchmark is 63 years and the maximum durability is 150 years. The estimated design life for the subject building "Escarpment View Escarpment View (As-Built)" is 50 years whilst the maximum durability is 50 years.

The Embodied Energy impact associated with the base case design totalled 4,714,456 MJ NCV

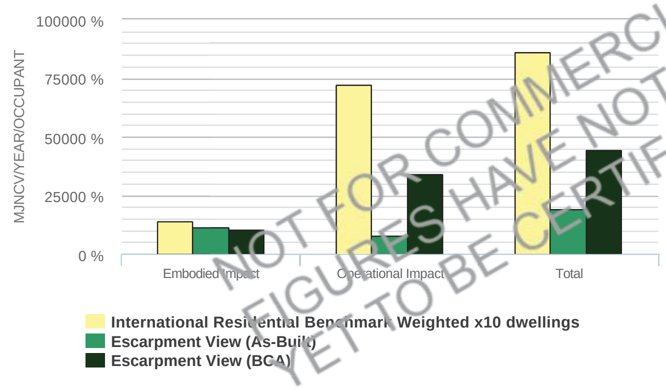
Taking into account the functional units of the building, this is equivalent to 18,858 MJNCV/year/Occupant. This represents a 78% saving compared to the benchmark.

With recommendations a saving of 48% can be achieved.

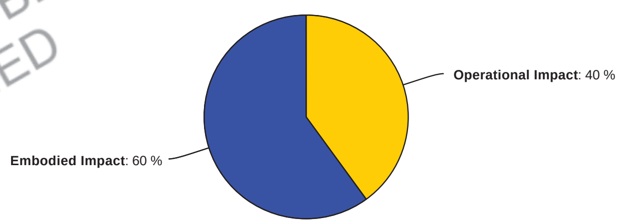
The following charts provide some further information regarding the comparative impacts of the three designs. A comparison has also been provided of the largest embodied and operational impacts. The detailed percentage split of impacts sources relating to the base case design have also been provided.

Total Life Cycle Embodied Energy

Comparison of Embodied Energy Profiles:

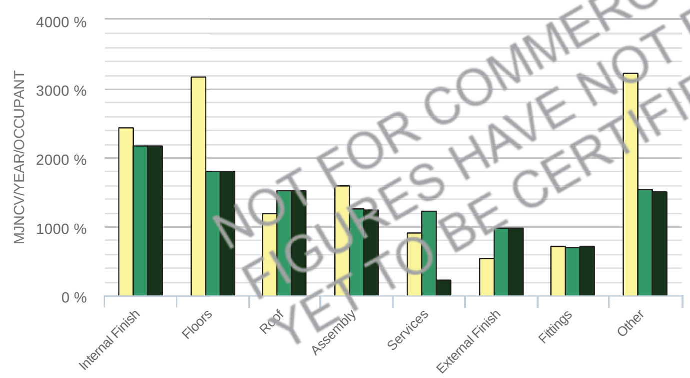


Total Embodied Energy Profile for Escarpment View (As-Built)



Embodied Embodied Energy

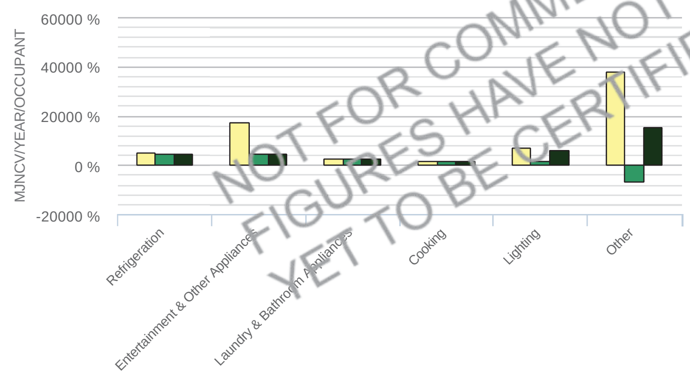
Comparison of Embodied Embodied Energy:



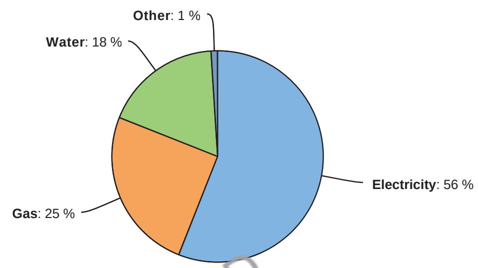
Embodied Embodied Energy Profile for Escarpment View (As-Built)

Operational Embodied Energy

Comparison of Operational Embodied Energy:



Operational Embodied Energy Profile for Escarpment View (As-Built)



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 construction works, the total life cycle energy consumption is made up of two elements:

- 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 construction works
- Conduct this in a cost effective, auditable and repeatable manner

A typical eTool assessment allows reporting of numerous impacts. This report only details the Embodied Energy 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 construction works, this will usually be overshadowed by the influence of occupant behavior on operational impacts, or the actual construction work 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
- Inflation of construction 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 structure which can be reported on separately. Please contact us for more information.

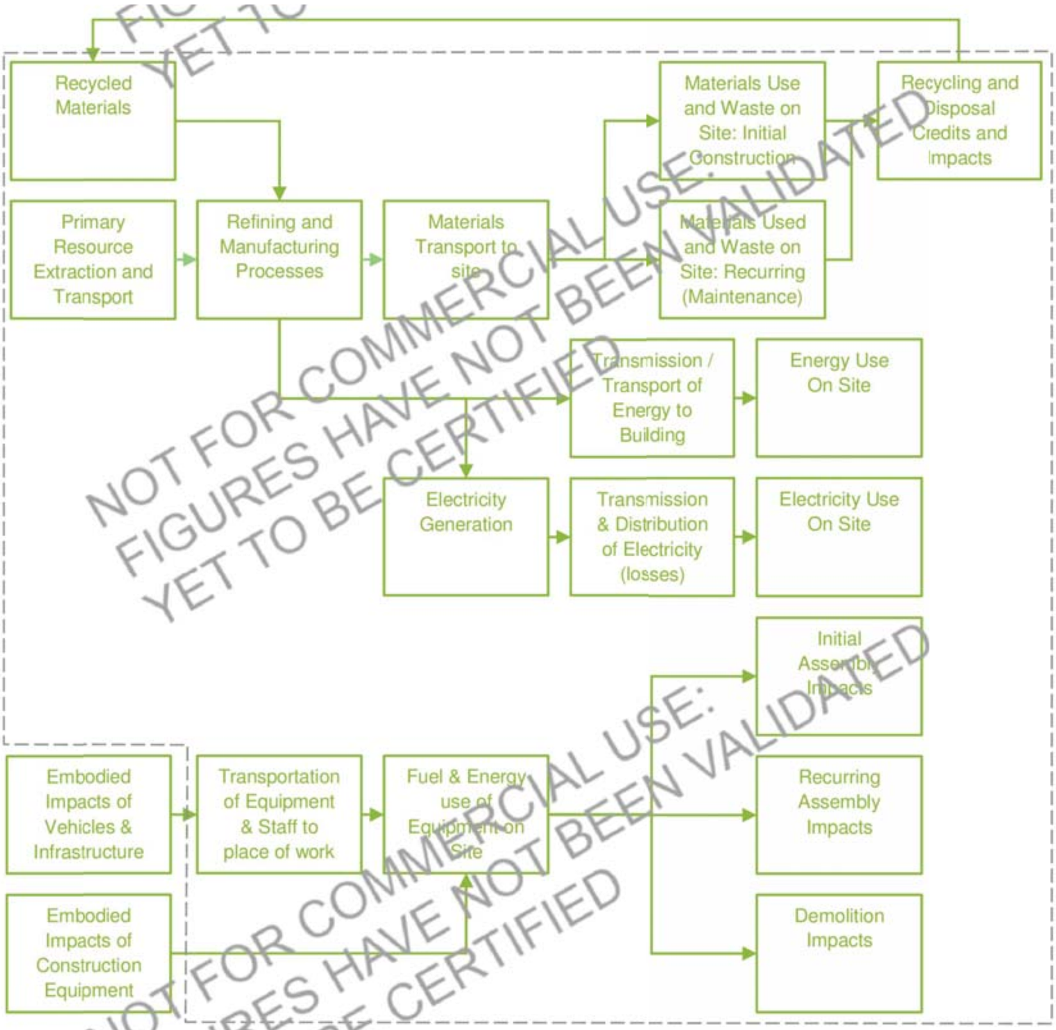


Figure 1: System Boundary of LCA

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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
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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.

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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 Embodied Energy for each of the designs assessed is outlined below:

- Escarpment View (As-Built): 4,714,456 MJ NCV
- International Residential Benchmark Weighted x10 dwellings: 133,230,035 MJ NCV
- Escarpment View (BCA): 11,111,182 MJ NCV

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:

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

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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).

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List of Major References

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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,
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Dynamics of Carbon Stocks in Timber in Australian Residential Housing, The Universtiy of Melbourne and NSW Department of Primary Industries, Forest and Wood Products Australia, 2009.
Energetics, Think Brick Australia - LCA of Brick Products, Energetics PTY LTD, 2010.
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.

APPENDIX N: RELEVANT AUSTRALIAN STANDARDS TO DOMESTIC HOUSE DESIGN AND CONSTRUCTION

Environmental Management:

- NSW Landcom publication titled Managing Urban Storm water: Soils and Construction Vol. 1, 4th ed. March 2004 (Blue Book)

Earthworks:

- AS 1141 Methods for sampling and testing aggregates
- AS 1141.23 Los Angeles value
- AS 1289 Methods of testing soils for engineering purposes
- AS 1289.5.1.1 Determination of the dry density/moisture content relation of a soil using standard compactive effort
- AS 1289.5.2.1 Determination of the dry density/moisture content relation of a soil using modified compactive effort
- AS 1289.5.3.1 Determination of the field dry density of a soil - Sand replacement method using a sand-cone pouring apparatus
- AS 1289.5.3.5 Determination of the field dry density of a soil - Water replacement method
- AS 1289.5.4.1 Compaction control test - Dry density ratio, moisture variation and moisture ratio
- AS 1289.5.6.1 Compaction control test - Density index method for a cohesion less material
- AS 1289.5.8.1 Determination of field density and field moisture content of a soil using a nuclear surface moisture-density gauge - Direct transmission mode
- AS 1289.5.8.4 Nuclear surface moisture-density gauges - Calibration using standard blocks
- AS 1289.6.1.1 Determination of the California Bearing Ratio of a soil - Standard laboratory method for a remoulded specimen
- AS 1289.6.1.2 Determination of the California Bearing Ratio of a soil - Standard laboratory method for an undisturbed specimen
- AS 1289.6.1.3 Determination of the California Bearing Ratio of a soil - Standard field-in-place method
- AS 1348.1 Road design and construction
- AS 1726 Geotechnical site investigations
- AS 3705 Geotextiles - Identification, marking and general data
- AS 3798 Guidelines on earthworks for commercial and residential developments
- AS 4678 Guidelines on backfilling retaining walls

Demolition and Asbestos Removal:

- AS 2436 Guide to noise control
- AS 2601 The demolition of structures
- CODE OF PRACTICE For the Safe Removal of Asbestos, Second Edition [NOHSC: 2002(2005)]

Concrete, Formwork and Finishing:

- AS 3600 Concrete structures
- AS 1379 The Specification and supply of concrete.

- AS 1478 Chemical admixtures for concrete, mortar and grout – Admixtures for concrete
- AS 2758 Aggregates and rock for engineering purposes - concrete aggregates
- AS 3582.1 Supplementary cementitious material for use with portland and blended cement - fly ash
- AS 3972 Portland and Blended Cements
- AS MP20 Part 1 - information on permeability - reducing admixtures for concrete
- AS 1012 Methods of testing concrete
- AS 1141 Methods for sampling and testing aggregates
- AS 3799 Liquid membrane-forming curing compounds for concrete AS 1523 Elastomeric bearings for use in structures.
- AS 1170 Structural Design Actions. Part O and Parts 1 – 4
- AS 3610 Formwork for concrete
- AS 3610 Formwork for concrete, supplement 1 and 2
- AS/NZ 4671 Steel reinforcing materials.
- AS 1444 Wrought alloy steels - standard, hardenability (H) series and hardened and tempered to designated mechanical properties.
- AS 1554 Structural Steel Welding Code - Part 3 - Welding of reinforcing steel.
- AS 1627 Meal Finishing – preparation and pretreatment of surfaces.
- AS 4534:1998 Zinc and zinc/aluminium-alloy coatings on steel wire.
- AS 4792:1999 Hot dipped galvanised (zinc) coatings on ferrous hollow sections, applied by continuous or a specialised process.
- AS 4680:1999 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles.
- AS 2159 Piling Code

Masonry:

- AS 1672.1 Limes for building
- AS 2699 Wall ties for masonry Construction
- AS/NZS 2904 Damp-proof courses and flashings
- AS 3582 Supplementary cementitious materials for use with portland cement
- AS 3582.1 Flyash
- AS 3600 Concrete structures
- AS 3700 Masonry in buildings (known as the SAA Masonry Code)
- AS 3972 Portland and blended cements
- AS 4072.1 Service penetrations and control joints
- AS/NZS 4455 Masonry units and segmental pavers
- AS/NZS 4456 Masonry units and segmental pavers - Methods of test
- AS/NZS 4456.6 Determining potential to effloresce
- AS/NZS 4456.7 Determining core percentage and material thickness
- AS/NZS 4456.8 Determining moisture content and dry density
- ASINZS4456.10 Determining resistance to salt attack
- AS/NZS 4456.11 Determining coefficients of expansion
- AS/NZS 4456.12 Determining coefficients of contraction
- AS/NZS 4456.13 Determining pitting due to lime particles
- AS/NZS 4456.14 Determining water absorption properties
- AS/NZS 4456.15 Determining lateral modulus of rupture
- AS/NZS 4456.16 Determining permeability to water
- AS/NZS 4456.17 Determining initial rate of absorption (suction)

- AS/NZS 4456.18 Determining tensile strength of masonry units and segmental pavers
- AS/NZS 4600 Cold-formed steel structure

Structural Steel:

- AS 4100 – Steel Structures
- AS 1085.1 – Steel rails
- AS/NZS 1111 – ISO metric hexagon commercial bolts and screws
- AS 1163 – Structural steel hollow sections
- AS 1237 – Flat metal washers for general engineering purposes (metric series)
- AS/NZS 1252 – High strength steel bolts with associated nuts and washers for structural engineering
- AS 1397 – Steel sheet and strip – Hot-dipped Zinc-coated or Aluminium / Zinc-coated
- AS/NZS 1554 – Structural steel welding
- AS/NZS 1554.1 – Welding of steel structures
- AS 1627 – Metal finishing – Preparation and pretreatment of surfaces
- AS 1627.4 – Abrasive blast cleaning
- AS 1710 – Non-destructive testing – Ultrasonic testing of carbon and low alloy steel plate – Test methods and quality classification
- AS/NZS 3678 – Structural steel – Hot-rolled plates, floor-plates and slabs
- AS/NZS 3679.1 – Hot-rolled bars and sections
- AS/NZS 3679.2 – Welded I sections
- AS/NZS 4600 – Cold-formed steel structures

Timber:

- AS 1080.1 – Timber – Methods of Test – Moisture Content
- AS 1604 – Specification for Preservative Treatment
- AS 1684 – Residential Timber–Framed Construction
- AS 1720 – Timber Structures
- AS 1859 – Reconstituted Wood Based Panels
- AS 2082 – Timber – Hardwood – Visually Stress-Graded for Structural Purposes
- AS 2098.11 – Methods of tests for veneer and plywood – Determination of formaldehyde emissions for plywood
- AS 2131 – Adhesives – For Bonding Decorative Thermoset Laminates (Contact Adhesives)
- AS 2269 – Plywood – Structural
- AS 2754 – Adhesives for Timber and Timber Products
- AS 4785 – Timber – Softwood – Sawn and Milled Products Fixings
- AS 1110 – ISO Metric Hexagon Bolts and Screws – Product Grades A and B
- AS 1111 – ISO Metric Hexagon Bolts and Screws – Product Grade C
- AS 1214 – Hot-Dip Galvanized Coatings on Threaded Fasteners
- AS 1237 – Plain Washers for Metric Bolts, Screws and Nuts for General Purposes
- AS 1390 – Cup Head Bolts with ISO Metric Coarse Pitch Threads
- AS 1393 – Coach Screws – Metric Series with ISO Hexagon Heads
- AS 1420 – ISO Metric Hexagon Socket Head Cap Screws
- AS 1421 – ISO Metric Hexagon Socket Set Screws
- AS 1427 – ISO Metric Machine Screws
- AS 2334 – Steel Nails – Metric Series
- AS 3566 – Self-drilling Screws for the Building and Construction Industries

- AS 4402 – Hexagon Head Tapping Screws
- AS 4412 – Heat-treated Steel Tapping Screws – Mechanical Properties
- AS 4680 – Hot-dip Galvanized (Zinc) Coatings on Fabricated Ferrous Articles Metal Studwork
- AS 1163 – Structural Steel Hollow Sections
- AS 1397 – Steel Sheet and Strip - Hot Dipped Zinc Coated or Aluminium/Zinc Coated
- AS 3679.1 – Structural Steel – Hot Rolled Bars and Sections
- AS 4100 – Steel Structures
- AS 4600 – Cold-formed Steel Structures

Glazing:

- AS 1231 – Aluminium and Aluminium Alloys – Anodic Oxidation Coating
- AS 1288 – Glass in Buildings – Selection and Installation Glass in Buildings.
- AS 2208 – Safety Glazing Materials in Buildings
- ASTM C509 Standard Specification for Elastomeric Cellular Preformed Gasket and Sealing Material
- AS 1397 – Steel Sheet and Strip - Hot-Dipped Zinc-Coated or Aluminium/Zinc Coated
- AS 1627 – Metal Finishing - Preparation and Pre-treatment of Surfaces
- AS 2311 – Guide to the Painting of Buildings
- AS 2796.1 – Timber – Hardwood – Sawn and Milled Products – Product & Specification
- AS 2796.2 – Timber – Hardwood – Sawn and Milled Products – Grade Description
- AS 2688 – Timber doors
- AS 4266 – Reconstituted Wood-based Panels – Methods of Test Finishing
- AS 1231 – Aluminium and Aluminium Alloys – Anodic Oxidation Coatings
- AS 2039 – Methods for Testing Anodic Oxidation Coatings on Aluminium and Aluminium Alloys

Interior Finishes:

- AS/NZS 2588:1998 Gypsum plasterboard
- AS 3958.1-2007 Ceramic tiles
- AS 1884-2012 Floor coverings
- AS 2870-2011, Residential slabs and footings.

Hydraulic:

- The National Construction Code of Australia (NCC)
- AS 3500 National Plumbing and Drainage Code
- AS 3588 Suitabilty of Plumbing and Water Distribution Systems Products for Contact with Potable Water
- AS 2179 Metal Rainwater Goods
- AS 1547 Disposal Systems for Effluent from Domestic Premises
- AS/NZS 2845 Water Supply - Backflow Prevention Devices
- AS/NZS 3497 Drinking Water Treatment Units - Plumbing Requirements
- AS 4348 Water Supply - Domestic Type Water Treatment Appliances - Performance Requirements
- NHMRC Guidelines for Drinking Water Quality in Australia
- ANSI/NSF 55 Ultraviolet Water Treatment Systems