Quantifying the Sustainability of the Built Environment: The Development of a Complete Environmental Life Cycle Assessment Tool

by
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DECLARATION

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Date: February 2015

Summary

Sustainability is becoming an increasingly important aspect in all facets of engineering. It is in particular an important consideration in the structural engineering industry, due to the prominence of the negative impact this industry has on the environment, both on a national and international scale.

The problem, however, is that sustainability is a mostly unknown and highly debated topic. It is not only difficult to quantify, but even difficult just to define. In the field of structural engineering it is an especially difficult task to consider sustainability. It is still a very new field of research and difficult to apply. It is therefore important that continued research be done in order for there to be a better understanding of how sustainability should be considered and applied in the context of structures.

In an attempt to assess the environmental impact of building structures, there are two basic approaches that are followed. The first, the application-oriented method, is a simple, points-based system. The second, the analysis-oriented method, makes use of detailed indices and factors to quantify the impact. This study aims to develop an analysis-oriented method, specifically designed for the complete life cycle of buildings in the South African environment. This is accomplished by continuing the work that was started by Brewis (2011), and continued by Brits (2012).

Brewis developed the approach for the pre-use phase, while Brits developed the approach for the end-of-life phase. Both focussed their application on low-cost housing development. However, the approach is defined for the use of the analysis of a building envelope. The details of developing the environmental life cycle assessment (LCA), as well as the approaches for the pre-use phase and the end-of life phase are discussed in Chapter 3.

The study develops the use phase of the proposed environmental life cycle assessment for buildings in Chapter 4. It discusses in detail the two main components of the use phase, namely maintenance and operation. While maintenance is concerned with the replacement of building materials in the structure, the operation component is concerned with the energy needs during the use phase.

It is determined that the energy use that is directly related to the building envelope is the energy required for the space heating and cooling of the building. This is due to the fact that the thermal properties of the building envelope influence the thermal environment within the building, and thereby impact the use of energy to regulate that thermal environment.

In order to make the most use of both of these components within the application of the proposed LCA, it was decided to model a residential building structure that uses consistent energy to regulate the thermal environment within the structure.

However, it is not only the objective to use the proposed LCA as an assessment tool, but also as a comparative and optimisation tool. Therefore one component, the external walls, was selected as a variable component. This component was varied to form a total of nine different buildings. These nine buildings were then used in a comparative study in order to try to determine an optimum choice of external walling system, based on the results of the environmental impacts determined in the LCA. It is also used to try to explain exactly how and to what extent the external walling system contributes to the environmental impact, and what useful application value we can gain from this knowledge.

The results showed that a minor increase in the materials impact (due to attempts to improve the thermal capacity of the external walls) were in most cases countered by a decrease in the energy impact, which in seven of the eight alternative external walling systems led to a net decrease in environmental impact (EI) categories one to four.

It was also found that with the increase of the R-value of the external walling systems, the environmental impact of the building steadily decreased, in terms of four of the five impact categories.

The only exception to these trends was found in the fifth impact category: waste generation. The reason for this is the fact that energy impact in this environmental impact category is negligible, and therefore does not contribute much to the net change in environmental impact.

OPSOMMING

Die belangrikheid van volhoubaarheid neem al hoe meer toe in alle aspekte van ingenieurswese. In die industrie van struktuuringenieurswese is dit van besonderse belang as gevolg van die prominente negatiewe impak van hierdie industrie op die omgewing, op beide ’n nasionale en internasionale skaal.

Die probleem is egter dat volhoubaarheid nog meestal gesien word as ’n onderwerp wat onbekend en hoogs debatteerbaar is. Dit is nie net moeilik om te kwantifiseer nie, maar selfs moeilik om dit net te definieer. In struktuuringenieurswese is dit veral ’n moeilike taak om volhoubaarheid in ag te neem. Dit is nog ’n baie jong studieveld wat moeilik is om toe te pas. Dit is dus van uiterse belang dat verdere navorsing gedoen word sodat daar ’n beter begrip kan wees van hoe volhoubaarheid op die lewensiklus van strukture toegepas kan word.

In 'n poging om die omgewingsimpak van die geboustrukture te evalueer, is daar twee basiese benaderings wat gevolg kan word. Die eerste, die toepassingsgeoriënteerde metode, is 'n eenvoudige, punte-gebaseerde stelsel. Die tweede, die analise-georiënteerde metode maak gebruik van gedetailleerde indekse en faktore om die omgewingsimpak te kwantifiseer. Hierdie studie beoog om 'n analise-georiënteerde metode te ontwikkel, wat spesifiek ontwerp is vir die analise van die volledige lewensiklus van geboue in die Suid-Afrikaanse omgewing. Dit word gedoen deur die voortsetting van die werk wat begin is deur Brewis (2011), en voortgesit is deur Brits (2012).

Brewis het die benadering vir die eerste fase (voor-gebruik) ontwikkel, terwyl Brits die benadering vir die finale fase (einde-van-lewe) ontwikkel het. Beide het die fokus van hul toepassings geplaas op lae-koste behuising. Die benaderings is egter gedefinieer vir die algemene analise van ’n gebou se raamwerk. Die besonderhede van die ontwikkeling van die omgewingslewensiklus analise (OLA), asook die benaderings vir die eerste en finale fases, word in Hoofstuk 3 bespreek.

Die studie ontwikkel die gebruiksfase van die voorgestelde omgewingslewensiklus analise vir geboue in Hoofstuk 4. Dit bespreek die twee hoofkomponente van die gebruiksfase, naamlik die instandhouding en bedryf. Terwyl instandhouding gemoeid is met die vervanging van boumateriale in die struktuur, is die bedryfskomponent gemoeid met die energie behoeftes tydens die gebruiksfase.

Dit word bepaal dat die energie verbruik wat ’n direkte verband het met die gebou se raamwerk, die energie is wat nodig is vir die verhitting en verkoeling van die gebou. Dit is te danke aan die feit dat die termiese eienskappe van die gebou se raamwerk die termiese omgewing binne die gebou beïnvloed, en sodoende 'n impak het op die energie wat benodig word om die temperatuur te reguleer.

In ’n poging om die spektrum van die voorgestelde OLA ten volle te benut, is dit besluit om die toepassing daarvan te illustreer op 'n residensiële gebou wat van konsekwente energieverbruik gebruik maak om die termiese omgewing binne die gebou te reguleer.

Dit is egter nie net die doel om die voorgestelde OLA te gebruik as 'n assesseringsinstrument nie, maar ook om die OLA se funksie as ’n vergelykende en optimaliseringshulpmiddel te illustreer. Dus is een komponent, die eksterne mure, gekies as 'n veranderlike komponent. Hierdie komponent is gewissel om 'n totaal van nege verskillende geboue te vorm. Hierdie nege geboue is gebruik in 'n vergelykende studie in 'n poging om 'n optimale keuse van eksterne mure te bepaal, gebaseer op die resultate van die omgewingsimpak wat in die OLA te bepaal is. Dit word ook gebruik om te probeer om te verduidelik presies hoe en tot watter mate die eksterne mure bydra by tot die omgewingsimpak, en watter nuttige toepassingswaarde geput kan word uit hierdie kennis.

Die resultate het getoon dat 'n toename in die materiaal impak (weens pogings om die termiese kapasiteit van die eksterne mure te verbeter) in die meeste gevalle teengewerk is deur 'n afname in die energie impak. In

sewe van die agt alternatiewe eksterne muurstelsels het dit gelei tot 'n netto afname in omgewingsimpak vir kategorieë een tot vier.

Dit is ook gevind dat die omgewingsimpak van die gebou stelselmatig gedaal het met die toename van die R-waarde van die eksterne muurstelsels, ook in terme van kategorieë een tot vier.

Die enigste uitsondering op hierdie tendense is gevind in die vyfde impak kategorie: die afval wat gegenereer word. Die feit dat die effek van energie verbruik gering is in hierdie omgewingsimpak kategorie, lei tot die feit dat dit nie veel bydra tot die netto verandering in die omgewingsimpak nie.

Acknowledgements

It is with tremendous gratitude that I would like to acknowledge the people who played the most important roles in the completion of this study.

Firstly, I would like to thank Chandré Brewis and Juané Brits for all of the research they did before me. Their work not only contributed to this study, but also encouraged my interest in the field of sustainability in structural engineering. I will be forever thankful for that.

Secondly, I would like to thank Francois Joubert, Thomas Hugo, and the entire team at Greenbuild Consultants for their invaluable input into my understanding of the DesignBuilder software and its application use in this study. Your generosity in this regard has no doubt led to a much-improved accuracy in my approach and calculations, and for this I am very grateful.

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And finally, to Wibke de Villiers: I am interminably grateful for your careful guidance, your support, as well as your endless patience with me. You were the person who first introduced me to the world of sustainability in structural engineering when I was still an undergraduate student, and have as such literally changed the course of my life.

This was not an easy journey, but you never wavered in your encouragement of my goals. You encouraged me to expand the research that I could, but also curbed my enthusiasm when I tried to attempt too much. I am so grateful for the way you have helped to shape my future. Thank you.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CDIAC	Carbon Dioxide Information Analysis Center
CExD	Cumulative Exergy Demand
CH	Location: "Switzerland" (in ecoinvent)
CIA	Central Intelligence Agency (United States of America)
CO_{2e}	Carbon Dioxide Equivalent
DPC	Damp-Proof Course
DPM	Damp-Proof Membrane
DWL	Design Working Life
EDIP'97	Environmental Design of Industrial Products (Version 1997)
EI	Environmental Impact
EII	Environmental Impact Index
EPS	Expanded Polystyrene
EPU	Expanded Polyurethane
FIDIC	International Federation of Consulting Engineers
GBCA	Green Building Council of Australia
GBCSA	Green Building Council of South Africa
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHS	General Household Survey
HVAC	Heating, Ventilating, and Air Conditioning
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LDC	Less-Developed Country
NHBRC	National Home Builders Registration Council
NIC	Newly Industrialized Country

NO_3^-	Nitrate
OECD	Organization for Economic Cooperation and Development
OLA	Omgewingslewensiklus Analise
OSB	Oriented Strand Board
RoW	Location: "Rest of the World" (in ecoinvent)
SABS	South African Bureau of Standards
SANS	South African National Standard
SO_{2e}	Sulphur Dioxide Equivalent
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
ZA	Location: "South Africa" (in ecoinvent)

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Chapter 1: INTRODUCTION

With the global population currently standing at 7 billion, and increasing at a steady rate, the topic of sustainability is growing more prominent. Sustainability is a necessity to ensure the longevity of life on earth. It is often considered in terms of three categories: economic, social, and environmental.

In terms of environmental impact, the construction industry is a major contributor to greenhouse gas (GHG) emissions, both on a South African and an international scale. It is therefore the responsibility of the professionals in the construction industry to find ways in which they can further the efforts of sustainability.

1.1. PROBLEM STATEMENT

Sustainability is difficult to define, and even more difficult to measure or quantify. However, in order to try to improve sustainability, it must first be assessed to some extent.

In South Africa the only measure of the "green-ness" of building structures is through a points-based method called the Green Star SA rating tool. It would be beneficial to have the option of analysing the environmental impact of buildings on a more technical scale. An analysis-oriented method would allow for the in-depth analysis of the environmental impact of a building, and contribute real values to these impacts, which can then be used to determine how and where to improve on the building design. It could, however, also be used as a comparative tool to evaluate the performance of different building designs, and be used in attempts to optimise buildings for sustainability.

1.2. MAIN AIMS

The central aim of this study was the development of a complete environmental life cycle assessment (LCA) tool for the built environment. This required the development of the three phases of a building life cycle: pre-use, use, and end-of-life. The pre-use phase was previously developed by Brewis (2011) and the end-of-life phase was previously developed by Brits (2012). This study focussed on the development of the use phase, and finally assembling all three phases into one complete, cohesive analysis tool.

The second aim of this study was to demonstrate the potential of such an environmental LCA as an analysis tool, but also as a comparative and optimisation tool. This was done through a specific application study.

The application study aimed to analyse the impact of a building designed to SANS[1] 10400-XA standards. It then aimed to use the analysis tool to compare different buildings and optimise the external wall design through the analysis of the same reference design building with a single variable—the external wall design. It also aimed to determine how the external walls influence the environmental impact through its impact on the thermal conditions within the building.

1.3. SCOPE

The proposed environmental life cycle assessment tool was developed to be used to analyse the environmental impact (EI) of the building envelope of any building in South Africa. It measures the environmental impact in terms of five environmental impact categories relevant to structures, namely carbon footprint (EI_1), acidification potential (EI_2), eutrophication potential (EI_3), resource depletion (EI_4), and waste generation (EI_5).

[1] SANS – South African National Standard

For the application of the proposed LCA in this study, a middle-segment home (sized 91m^2) was designed according to SANS 10400-XA standards. The location of this home was chosen as Cape Town, South Africa, and it was also assumed that this home is consistently mechanically ventilated to maintain the indoor temperature range as it is required by the SANS 10400-XA.

All results obtained from the application analyses are therefore only directly applicable to middle-segment residential buildings that make use of mechanical ventilation for space heating and cooling.

1.4. Methodology

The first step in this study was to analyse the two phases that had already been developed and to understand their value and purpose in the LCA tool as a whole. The next step was to develop the use phase in a manner that is consistent with the previously developed phases.

This was done by considering the two main components of the use phase of a building's life cycle: maintenance and operation (see Figure 1-1).

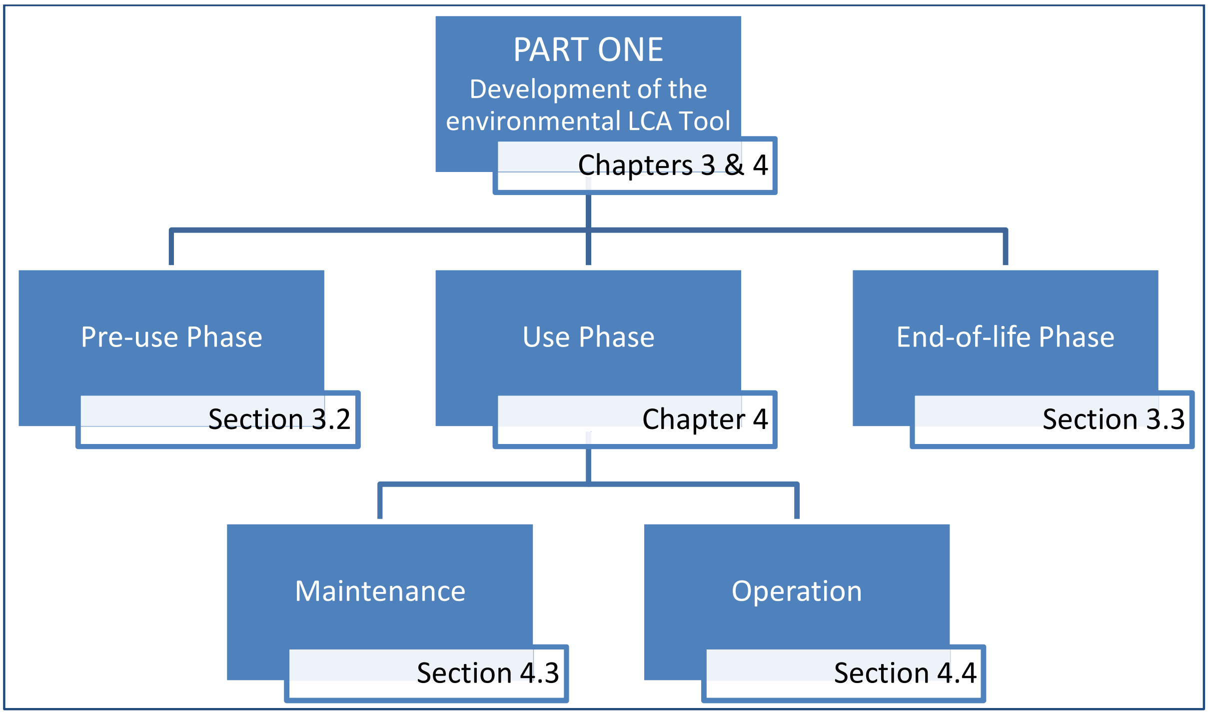


FIGURE 1-1: OUTLINE OF THE FIRST SECTION OF THE STUDY

Maintenance was developed through a combination of the pre-use and end-of-life phases. When maintenance takes place, the components that are removed follow an end-of-life cycle, while the new components that are installed follow a pre-use cycle.

Operation was developed by analysing the energy usage directly related to the building envelope. This was found to be all energy needs required for the heating and cooling of the building. This is due to the fact that the thermal capacities of the materials that make up the building envelope directly impact the thermal environment inside the building. As such, changes in building envelope will influence the amount of energy that is needed to heat or cool the building.

All three phases were then combined to form the complete environmental LCA, with assumptions being made to ensure consistency across all the phases.

The next step was to define and design a reference building to be used as a case study (Figure 1-2). As previously mentioned, this reference building was designed to meet all the minimum requirements as set out in SANS 10400-XA, as well as the other SANS codes related to the structural components. This reference building was then analysed and the results were used to illustrate the LCA tool's capacity as an analysis tool.

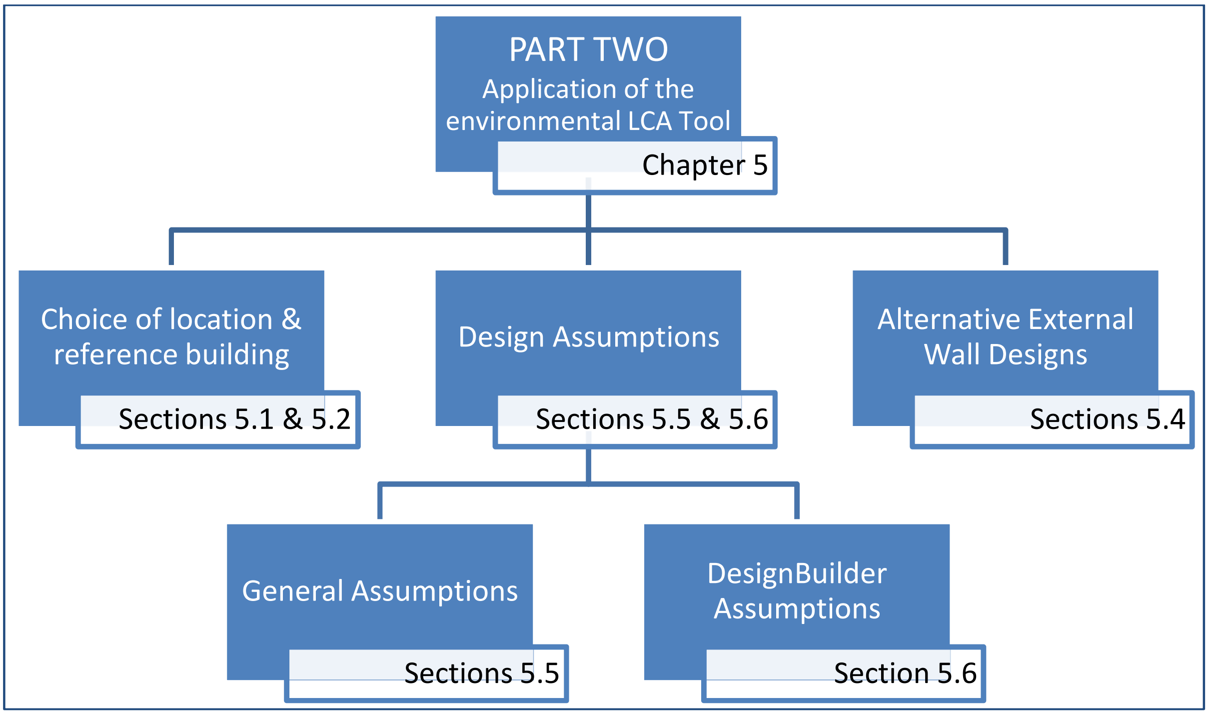


FIGURE 1-2: OUTLINE OF THE SECOND SECTION OF THE STUDY

The final step was to adapt the reference design by changing one variable component, namely the external walls. The alternative designs were then analysed and the results were compared with those of the reference building, in order to determine the optimised results.

Chapter 2: Study Motivation and General Background Information

2.1. Sustainability

Sustainability has been defined in many different ways, but one of the most commonly referenced definitions can be attributed to the Brundtland Report (WCED, 1987:15):

> *Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.*

It is a concept that has become critical in a world that is expanding at an exponential rate (as shown in Figure 2-1). If resources are used at a consistent rate, the lifespan of the finite resources will shorten as the population grows. In the case of renewable resources, the rate at which resources are depleted could outgrow the rate at which the resources can be replenished, making it, in effect, also a finite resource.

In order to ensure a sustainable future, it is therefore important that resources are used in a responsible and sustainable manner in the present.

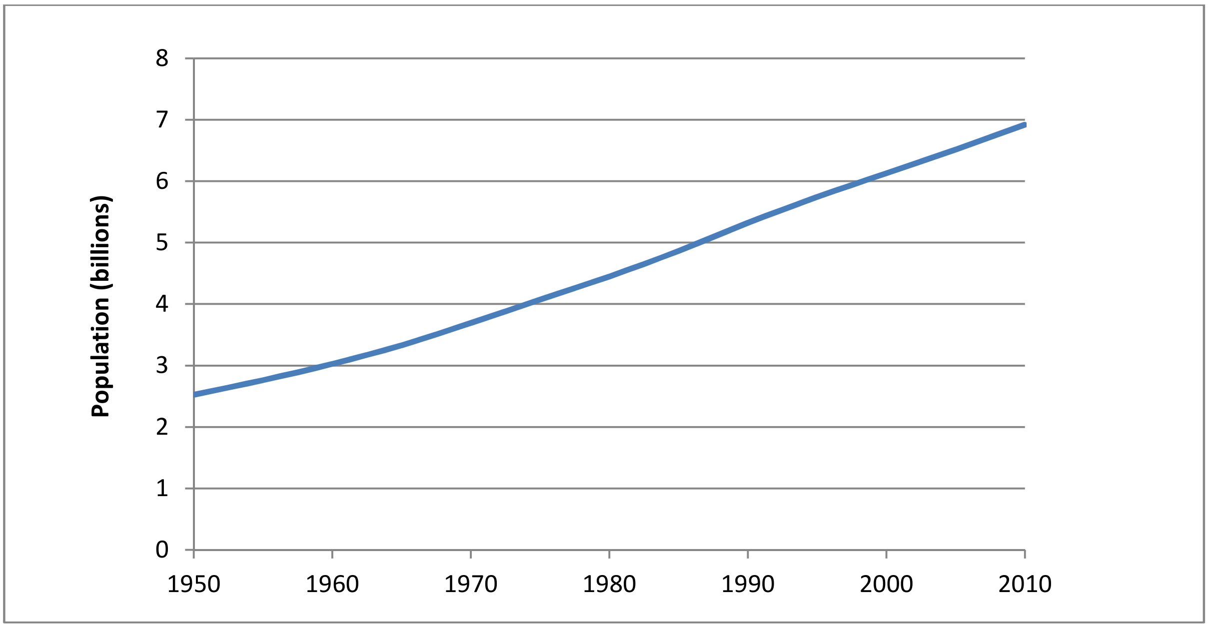


FIGURE 2-1: WORLD POPULATION (1950 - 2010)[2]

In an attempt to simplify the idea of sustainability, it can be divided into three categories, namely environmental, economic and social. This is referred to as the triple bottom line (Michelcic & Zimmerman, 2010:4). These categories are connected and can influence each other, but it is difficult to quantify the importance of each category in relation to another. Quantifying sustainability in each separate category is also difficult, but more reasonable.

While all three categories play an important role in the building sector, the environmental impact is currently an important topic due to the forthcoming implementation of carbon tax in South Africa (Department: National Treasury, 2013:7). It has also been noted by FIDIC (International Federation of Consulting Engineers)

[2] Chart compiled from data gathered from UNESA (2012).

that engineers in many low and middle income countries place emphasis on developing social and socio-economic issues, but do not have sufficient exposure to environmental issues (FIDIC, 2004:17). For these reasons, the study will focus on quantifying the environmental impact of buildings.

While the environmental impact will be the primary consideration of sustainability for this study, the results should still be considered in conjunction with economic and social factors.

2.2. South Africa

This study will focus on the residential sector of the structural environment in South Africa, with a specific application being considered in the Western Cape. It is therefore important to consider the specific factors that have a bearing on this environment.

2.2.1. Classification

South Africa is generally classified as a developing country (also referred to as a less-developed country or LDC). Farlex Financial Dictionary (2012) defines an LDC as follows:

> *A country with lower GDP[3] relative to other countries. Less developed countries are characterized by little industry and sometimes a comparatively high dependence on foreign aid. Less developed countries often undertake programs of development, with greater or lesser interventions on the part of the national governments. They are major borrowers from organizations such as the World Bank. While no strict definition of which countries are less developed exists, most countries that do not belong to the OECD[4] are considered less developed.*

However, this has become a disputed matter (as this classification system is not exact). South Africa most popularly falls within the LDC category called Newly Industrialized Countries (NIC). These are countries that have not yet reached the status of Developed Country, but have to some extent surpassed their counterparts in the Developing Country category. Most of the NIC countries have a GDP per capita of about 8000 to 18000 international dollars (according to figures provided by the World Bank in 2011).

However, the Central Intelligence Agency (CIA) has classified South Africa as a Developed Country (CIA, 2012). Although they state that South Africa falls way below their criteria for a Developed Country (a GDP per capita in excess of $15 000), they do not give an explanation for including South Africa as a Developed Country.

As such, for the purpose of this project, it would be most accurate to classify South Africa as a NIC.

2.2.2. Implications of Classification

It is important to know what shortcomings/restrictions South Africa has solely due to the fact that it is still a NIC. This study will focus in particular on South Africa's shortcomings in terms of energy supply and economy. When analysing the built environment, and its ability to achieve sustainability in certain areas (in this case specifically 'building materials' and 'energy'), this is an important consideration.

South Africa does not lack the capacity for world class development, and has proven as much in several areas. However, what is lacking (and this is clear when considering the GDP per capita) is that South Africa most often lacks the resources required for extensive research, development, and implementation.

Various options in terms of unique alternative building materials and systems have already been developed, while several others are waiting for testing and approval. The problem however is that these materials are not

[3] GDP – Gross Domestic Product

[4] OECD – Organization for Economic Cooperation and Development

mainstream, and will most likely not receive the opportunity to become such. These materials are in low demand, expensive and not always properly developed (due to lack of time/funds). It would take large investments to bring these materials to the mainstream structural industry.

The main focus when attempting to achieve sustainability is most often placed on energy. The biggest problem that South Africa faces in this respect is lack of options. Eskom currently produces 96% of the energy in South Africa (Statistics South Africa, 2012a), with the majority of their power plants being coal-fired. According to the Department of Energy of the Republic of South Africa an estimated 77% of South Africa's energy needs are met through coal.

2.2.3. Environmental Impact

Coal is an affordable source of energy, which is why coal-produced energy is so prevalent, but it is also the reason that South Africa is one of the world's top twenty carbon dioxide emission producers (latest confirmed numbers listing South Africa as twelfth in 2010), as well as being the largest producer of carbon dioxide emissions in Africa (United Nations Statistics Division, 2013b).

According to statistics from 2006, the building sector was responsible for a total of 23% of greenhouse gas emissions in South Africa (10% for commercial and 13% for residential) as seen in Figure 2-2 (Milford, 2009:33).

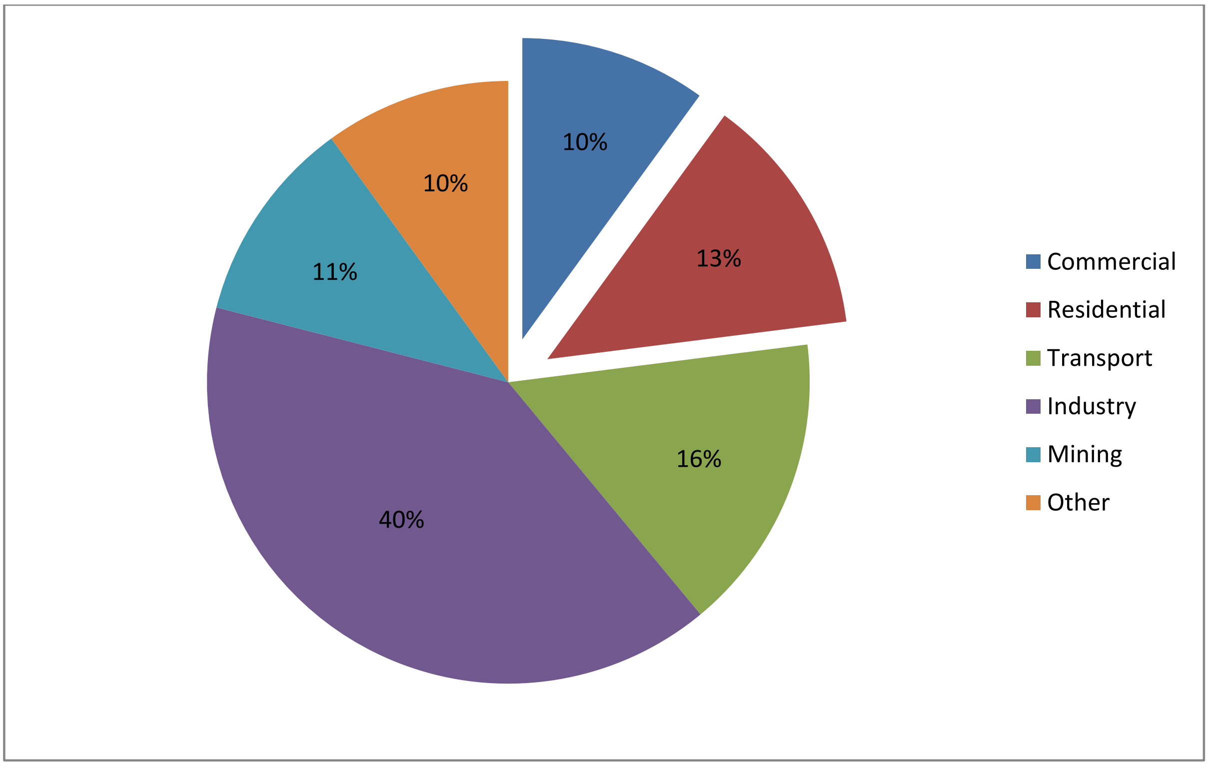


FIGURE 2-2: DISTRIBUTION OF GHG EMISSIONS ACCORDING TO SECTORS (SOUTH AFRICA, 2006)

As a part of an industry that contributes to almost a quarter of the country's GHG emissions, it is the responsibility of the professionals in the building sector to attempt to effect change in such a way to ensure a sustainable future.

2.3. SANS 10400-XA

SANS 10400 is the standard that deals with the application of the National Building Regulations. Part X of this deals with the topic of environmental sustainability and currently only consists of part XA (Energy Usage in Buildings).

This standard was first published in August 2011 and is an attempt to enforce energy efficiency in the South African building industry.

2.3.1. Design Routes for Compliance

There are two different routes of compliance in terms of Part XA: prescriptive design (also referred to as deemed-to-satisfy) or rational design. These two designed routes are briefly discussed below.

2.3.1.1. Prescriptive Design (Deemed-to-satisfy)

Part XA offers specific regulations for minimum thermal performance of floors, external walls, fenestration and roofs. These regulations are, however, subject to specific design assumptions.

The standard also lists requirements for hot water supply and energy usage. For the purpose of the energy calculations, however, the standard does not offer options for residential buildings. It is therefore not possible to use the prescriptive design route for design of residential buildings.

Table 2-1: Classification of buildings for energy usage calculations (SANS, 2011c:7)

Classification of occupancy of building	Description of building
A1	Entertainment and public assembly
A2	Theatrical and indoor sport
A3	Places of instruction
A4	Worship
F1	Large shop
G1	Offices
H1	Hotel

For buildings where prescriptive design is an option, it is also particularly restrictive in its regulations. The regulations are set to the same standard, with little to no consideration on the type of buildings, and gives minimum requirements for all components, with no room for deviation in cases where other components would void the effect of such a deviation.

2.3.1.2. Rational Design

The rational design route allows much more freedom in the design of buildings—there are no specific thermal requirements for the structural components. There are two methods to the rational design route.

Both methods require that the energy consumption of the building must be calculated with the use of:

(a) certified thermal calculation software
(b) climatic data provided by Agrément South Africa
(c) specific design assumptions as set out in Section 4.3 of SANS 10400-XA

Once the energy consumption has been calculated there are two methods that can be used to ensure compliance.

The first option is once again restricted by the definitions mentioned in Table 2-1. If the building being designed is listed in Table 2-1, the energy calculation results can simply be compared to the energy restrictions supplied in Part XA.

The second option is to compare the energy consumption to the energy consumption of a reference building, which must also be calculated with the thermal calculation software. The reference building is a building with the exact same footprint as the design building, but with all components designed according to the restrictions in Part XA. This is currently the only acceptable method to use when confirming Part XA compliance of a residential building.

2.3.2. Revisions and Expansion

As this is the first version of this specific standard, it is still a work-in-progress. There are already revisions being made, one example being the expansion of the climate region map, which is currently divided into only six climatic zones (Joubert, 2014).

Another part that is under revision is the section which deals with the requirements for external walls (Henshall-Howard, 2013). This section gives minimum requirements regarding the thermal resistance (known as the R-value) of the external walls of a building.

2.3.2.1. R-value

According to SANS 6946 (2007:4) the design thermal resistance of a component can be calculated as follows:

$$R = \frac{d}{\lambda} \tag{1}$$

Where R is measured in $m^2 \cdot K/W$

d is the thickness of the specific material (m)

λ is the design thermal conductivity of the material, measured in $W/(m \cdot K)$

K is temperature, in unit Kelvin

W is power, in unit Watts

The R-value is therefore inversely proportional to the thermal conductivity (with a constant thickness), and directly proportional to the thickness (with a constant conductivity).

According to Jelle (2011:2557) traditional insulation materials have thermal conductivities that are too high, and therefore require excessively thick components in order to ensure a zero-energy building (specifically in colder climates, thus relating to space heating needs). This leads to the fact that lowered thermal conductivity, and in turn higher R-values, should deliver buildings that are more energy efficient.

2.3.2.2. Energy Efficiency and External Walls

Many studies have considered the optimisation of insulation thickness in external walls and other building components in order to decrease energy consumption. In these cases the insulation material, and therefore the thermal conductivity, is kept constant. Generally the optimum insulation thickness is reached by increasing the thickness, thereby increasing the R-value. There is therefore a correlation between an increased R-value and increased energy efficiency.

This can be seen in a study by Çomakh & Yüksel (2004:938), which found that 53% of the building heat loss (in that specific study) happened through the external walls, ceiling, and flooring (with 40% being attributed to the external walls). When increasing the insulation thickness to an optimum value (and thereby increasing the R-value) it was found that the fuel consumption of the building was reduced to a point where CO_2 emissions were reduced by 27%.

Another study by Ozel (2011:3862) considered the optimum insulation thickness required for five different wall materials, and considering two different types of insulation materials. This study found that materials with the lowest thermal conductivity required the lowest optimum insulation thickness for thermal efficiency (illustrated in Figure 2-3). These optimum thicknesses were also directly linked to energy savings for the buildings.

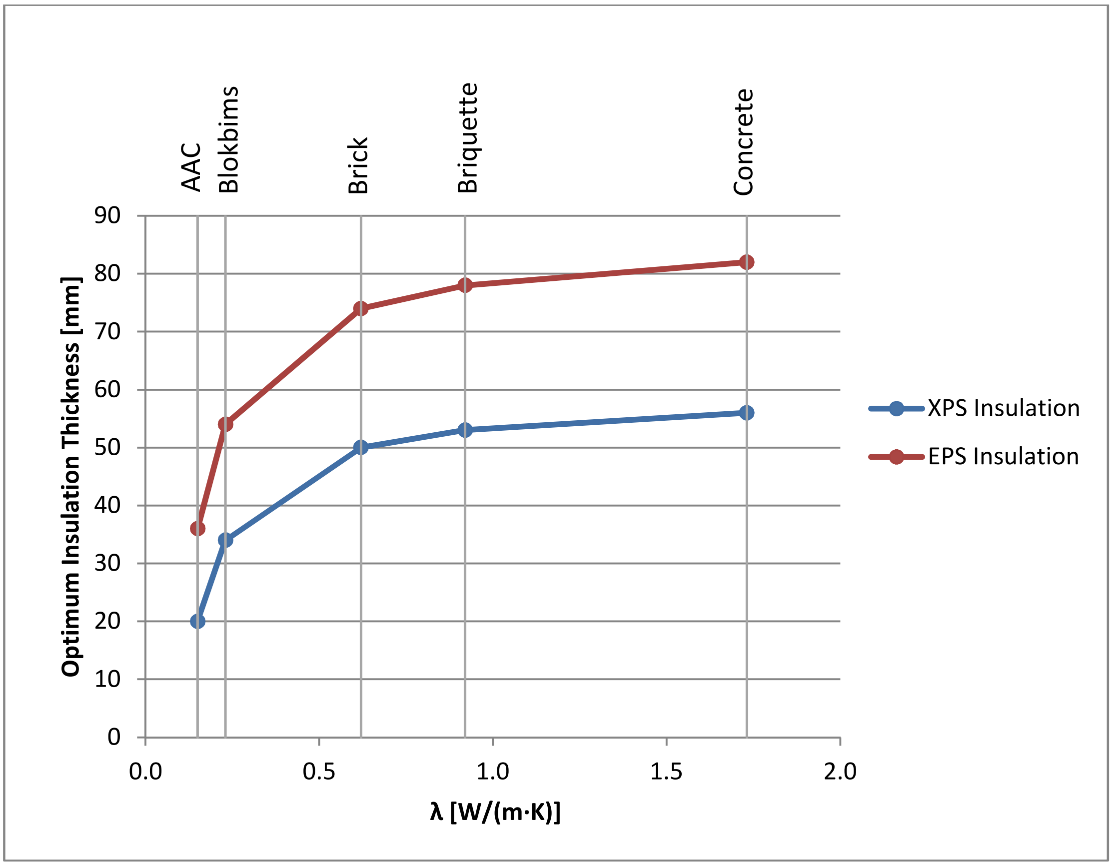


FIGURE 2-3: RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY & OPTIMUM INSULATION THICKNESS [OZEL, 2011:3862]

It is therefore useful to consider not only the thickness of the insulation materials, but also the specific types of insulation materials used (with specific focus on the thermal conductivity of the materials). An increased R-value can be achieved through either increasing the thickness or lowering the thermal conductivity. It is important to realise that simply considering an increase in the insulation thickness leads to higher material requirements, which in turn leads to higher environmental impacts. It is therefore important to consider both options when attempting to find an optimum wall construction.

This theory is considered and applied with the use of the proposed LCA as an optimisation tool in Chapter 7.

2.3.3. Additional Factors affecting the Building Envelope

In addition to the requirements regarding the external walls, there are also minimum R-value requirements for the floors and roof assemblies. The R-values, however, are not the only requirements with regard to the structures. The following requirements should also be taken into account when designing structures.

2.3.3.1. Building Orientation

The orientation of the structure is important in terms of solar gains and heat losses, and can therefore have a significant impact on the interior temperature.

Part XA offers several recommendations with regard to the orientation for optimum energy efficiency. This includes orienting the long axis of the building in an east-west direction and placing the most-used rooms and largest glazing areas on the northern side.

It's important to note that it is not always possible to strictly apply these guidelines, but it should at least be attempted.

2.3.3.2. Climatic Data

The climatic zone is an important consideration for thermal calculations, as the external climatic conditions determine the internal thermal environment. The South African map in the Part XA is currently divided into six climatic regions, with only one city's data available for each of these regions.

Due to the climatic data's prominence in calculations, the same climatic data must be used when comparing different structures.

2.3.3.3. Ventilation

Part XA requires that mechanical ventilation restricts the interior temperature to a range of 19°C to 25°C. This range applies to all locations in South Africa, irrespective of the specific climatic conditions.

2.3.3.4. Occupancy

There are currently no occupation schedules available for residential buildings in Part XA, and it is therefore required to assume a 24/7 schedule (Hugo, 2014). This is an unrealistic assumption which could have a significant effect on the energy usage of the building structure.

2.4. Environmental Impact Calculation

Calculating the environmental impact is a difficult and highly-debated subject. There are many different forms of environmental impact, which makes one concise, logical answer near-impossible.

There are two different approaches to analysing the environmental impact (Lui *et al*., 2010:1482).

2.4.1. The Application-oriented Method

The application-oriented method is a basic checklist method that makes use of building lifecycle theory to determine the environmental impact. It is straightforward and easy to use, but as such is, in most cases, an extremely simplified method.

The Green Star SA rating system is an example of this type of method. It is currently the only indicator of the environmental impact of buildings in South Africa. It was adapted from the Australian Green Star rating system by the Green Building Council of South Africa (GBCSA) and is still expanding and developing. It currently allows rating for the following categories of new buildings:

- Multi-Unit Residential
- Public & Education Building
- Office
- Retail Centre

Green Star SA is a points-based system, with points being awarded by meeting specific benchmarks in categories such as Energy, Transport and Water.

2.4.2. The Analysis-oriented Method

The analysis-oriented method is also based on building lifecycle theory, but makes use of more intricate analysis procedures, such as environmental indices, and normalisation and weighting systems.

The environmental LCA method proposed in this study will fall in this category and will be further discussed in Chapters 3 and 4.

Chapter 3: Development of an Environmental Life Cycle Assessment Tool

The purpose of the first part of this study is to develop a complete environmental life cycle assessment tool that can be used to quantify the environmental impact of any building. The tool will be able to deliver results of the environmental impact for individual indicators, as well as a cumulative environmental impact result. These results can be considered across the different life cycle phases, or for individual parts of the building.

Two Masters graduates from the University of Stellenbosch have already devoted their theses to use a life cycle approach to determine the sustainability of buildings. Brewis (2011) devoted her study to the analysis of the pre-use phase, while Brits' study (2012) analysed the end-of-life phase. In order to tie these together to create a complete life cycle assessment of a building, the use phase must be analysed.

3.1. The Scope

3.1.1. Defining the Building

This method aims to provide an accurate assessment of the environmental impact of a building. As such, the boundaries of this method must be clearly defined in order to acquire results that are comparable.

For the purposes of this study, the parts of the building which will be included in the analysis will constitute of the building envelope, as well as the energy use directly affected by the building envelope.

The building envelope will include all building materials that form the following parts of the building:

- Foundation
- Floor
- External Walls
- Internal Walls
- Ceiling Insulation
- Roofing and Roof Covering

The services (plumbing and electrical) and the finishes (paint, windows, doors, etc.) have not been included in the scope of this study. Although these aspects can differ, they are generally standardised across homes, and will be assumed as such for this study.

3.1.2. The Method

In order to quantify the entire environmental life cycle impact of a building it must be analysed through its complete existence: from the procurement of each individual raw material that will be used to construct the building to the eventual disposal of each building component. A representation of a building's life cycle can be seen in Figure 3-1.

Many different quantification methods exist and are consistently used to determine the environmental impact. The aim of this LCA is to provide an assessment that is both useful and easy to interpret.

The LCA that is proposed in this study will make use of an analysis-oriented method. This method requires the use of cumulative life cycle impact assessment (LCIA) results, as well as normalization and weighting factors. These LCIA results have been obtained from the ecoinvent database.

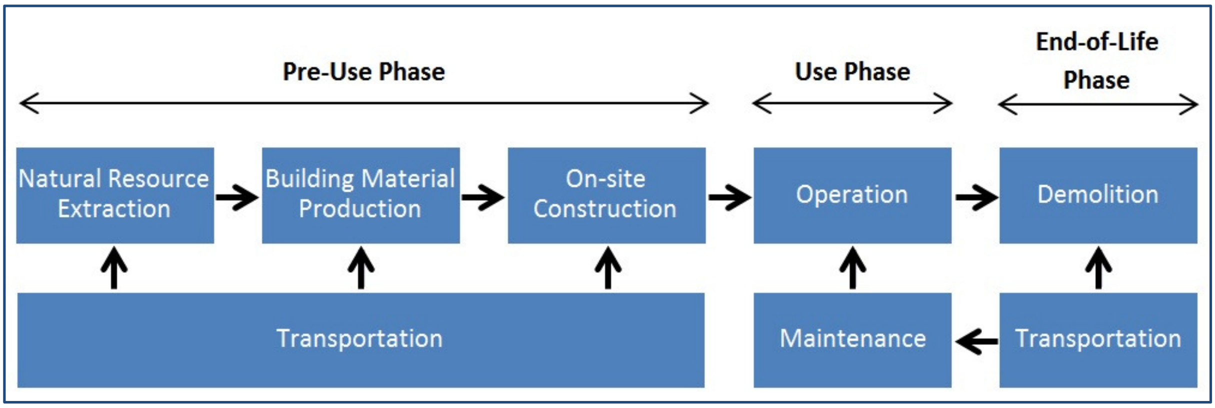


FIGURE 3-1: BUILDING LIFE CYCLE (WANG *ET AL.*, 2005)

3.1.2.1. ECOINVENT

ecoinvent is an online life cycle inventory (LCI) database. It provides inventory data from 19 methods (including different/updated versions of the same methods) as well as a collection of selected LCI results.

As part of the latest release of ecoinvent, there was an extensive expansion of the inventory, allowing for an increase in region-specific data. Data related to South Africa, however, is still scarce and therefore global factors were used in all calculations relating to building materials.

Improvements have been made, however, with the inclusion of South African data related to all different types of electricity production. It was therefore decided to use the region-specific data for the environmental impact of electricity generation; i.e. the ecoinvent values as provided for coal-generated electricity in South Africa. This choice was made with regards to the statistics discussed in Section 2.2.2.

Brewis chose the methods that were used as the sources for the LCIA results used in the proposed LCA, based on the chosen indicators. The two methods are briefly discussed below.

3.1.2.2. ENVIRONMENTAL DESIGN OF INDUSTRIAL PRODUCTS (EDIP)

The EDIP'97 method was developed in the mid-1990's as a collaborative effort between the Technical University of Denmark, the Danish Environmental Protection Agency and several Danish industry companies.

This method provides environmental indices for greenhouse gases, photochemical ozone formation, acidification and nutrient enrichment, ecotoxicity and human toxicity, long-term emissions, and waste.

EDIP'03 was introduced in 2003 and is an expansion of EDIP'97 that contains characterisation modelling that is spatially differentiated. It does not, however, replace the EDIP'97 method (Hischier *et al*., 2010:97).

3.1.2.3. CUMULATIVE EXERGY DEMAND (CExD)

The Cumulative Exergy Demand method only provides data for the category of cumulative exergy demand. The implementation of CExD in ecoinvent allows for exergy calculation in ten sub-categories, of which seven are energy resources and three are material resources (Hischier *et al*., 2010:41).

The energy resource sub-categories are: fossil, nuclear, wind, solar, water, primary forest, and biomass.

The material resource sub-categories are: water resources, metals, and minerals.

3.2. The Pre-Use Phase (Brewis' Model)

The pre-use phase of the proposed LCA was calculated as suggested by Brewis (2011). For a detailed description of the approach, calculations, as well as a detailed explanation about the selection of each indicator and its relevance to the South African building sector, Chapter 3 of Brewis (2011) can be consulted.

Three environmental indicators were considered as part of the model, namely Emissions, Resource Depletion and Waste Generation. A brief summary of each indicator and its analysis approach is included in this study for clarity.

3.2.1. Emissions

For the purpose of the pre-use phase of a building it was found that the two most important emissions to consider are the carbon footprint and the acidification potential.

The amount of gas (kg) that is emitted in each sub-category can be calculated with the following equation:

$$E_i = e_i m_i \tag{2}$$

Where e_i is the emission factor for a process, usually expressed as $kg\ (emission\ gas)/(unit\ of\ process)$

m_i is the mass/flow of the process

3.2.1.1. Carbon Footprint

As mentioned in Section 2.2.3, GHG emissions are important considerations in the South African context. All GHG emissions can be expressed in the form of a carbon dioxide equivalent (CO_{2e}), which makes them comparable—this is called the carbon footprint (measured in kg CO_{2e}).

$$EI_1 = CF = \sum_{i=1}^{n} GWP_i E_i \tag{3}$$

Where E_i is the amount of a specific gas, as calculated with Equation (2)

GWP_i is the global warming potential factor (Table 3-1)

The 100 year time horizon for the GWP has been chosen in accordance with the decision made by the parties to the United Nations Framework Convention on Climate Change (UNFCCC) (UN, 1996:18).

Table 3-1: GWP factors (Pachauri *et al.*, 2007)

GHG Name	Chemical Formula	GWP factor (100 year time horizon)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous Oxide	N_2O	310

Emission factors for this impact category are obtained from the EDIP'97 method in the ecoinvent database. NB: The GWP_i factor is already brought into calculation by the EDIP'97 method, and therefore the e_i factor obtained from ecoinvent is in the form of kg CO_{2e}/unit of process.

3.2.1.2. Acidification Potential

Air pollutants such as SO_2 and NO_x cause acidification of water resources and soil by forming acids. The potential of acidification is expressed in the form of mass of sulphur dioxide equivalent (kg SO_{2e}).

$$EI_2 = AP = \sum_{i=1}^{n} f_i E_i \qquad (4)$$

Where E_i is the amount of a specific gas, as calculated with Equation (2)

f_i is the acidification factor (Table 3-2)

TABLE 3-2: ACIDIFICATION FACTORS (AZAPAGIC *ET AL.*, 2004)

Gas Name	Chemical Formula	Acidification factor
Sulphur Dioxide	SO_2	1
Oxides of Nitrogen	NO_x	0.7

Emission factors for this impact category are obtained from the EDIP'97 method in the ecoinvent database. NB: The f_i factor is already brought into calculation by the EDIP'97 method, and therefore the e_i factor obtained from ecoinvent is in the form of kg SO_{2e}/unit of process.

3.2.2. Resource Depletion

The concept of exergy is used to calculate resource depletion in units of MJ_{ex}. The resource depletion of a product is described as the Cumulative Exergy Extraction from the Natural Environment ($CEENE_j$) and is calculated as follows:

$$EI_4 = CEENE_j = \sum_{i=1}^{n} X_i a_{ij} \qquad (5)$$

Where X_i is a conversion factor of the specific process (in MJ_{ex}/unit)

a_{ij} is the amount of the process i needed to produce product j

Conversion factors for this impact category are obtained from the CExD method in the ecoinvent database. Although the CExD method contains ten sub-categories for this factor, only the four relevant categories are included in the calculation:

- Fossil
- Water Resources
- Metals
- Minerals

For more information on the relevance of these sub-categories in the South African context, see Brewis (2011).

3.2.3. Waste Generation

Waste generation happens in two parts of the pre-use phase: there is first waste generation during production, and then again during construction. Waste generation is defined as the amount of waste disposed at landfills (measured in kg).

$$EI_5 = M_d = M - M_r \tag{6}$$

Where M is the total amount of waste generated in the pre-use phase (in kg)

M_r is the amount of the total waste that can be recycled (in kg)

M_d is the reduced amount of waste disposed at landfills (in kg)

3.2.3.1. Production Waste

Production waste factors for this impact category are obtained from the EDIP'97 method in the ecoinvent database. These factors are measured as kg waste per unit of process.

$$Production\ Waste = production\ waste\ factor \times amount\ of\ process \tag{7}$$

3.2.3.2. Construction Waste

Construction waste is calculated in accordance with the Spanish model suggested in Solis-Guzman *et al.* (2009). It is a six-step process that can be summarised by the following equation:

$$\begin{aligned} Construction\ Waste &= \rho \times building\ area \times (VAR_i + VAE_i) \\ &= \rho \times building\ area \times [(VAC_i \times CR_i) + (VAC_i \times CE_i)] \end{aligned} \tag{8}$$

Where VAR_i is the Apparent Wreckage Waste Volume measured in m^3/m^2

VAE_i is the Apparent Packaging Waste Volume measured in m^3/m^2

VAC_i is material quantity/m^2 of the building [unit/m^2], multiplied by conversion factor CC_i [m^3/unit]

CR_i & CE_i are dimensionless coefficients of transformation

ρ is the density of the material

A collection of factors, as well as instructions on the calculations can be found in Solís-Guzman *et al.* (2009).

3.2.4. Proposed Environmental Impact Index

The proposed environmental impact index (EII) can be calculated with the following equation:

$$EII = \sum_{i=1}^{n} c_i EI_i \tag{9}$$

Where c_i is the weighting factor related to each environmental impact index

Normalisation and weighting factors are taken from the EDIP'97 method. As such, the resource depletion cannot reasonably be included in the EII calculation, as it was derived from a different method. It can, however, be analysed on its own.

3.3. The End-of-Life Phase (Brits' Model)

The end-of-life phase of the proposed LCA was calculated as suggested by Brits (2012). For a detailed description of the approach, calculations, as well as a detailed explanation about the selection of the additional indicator and its relevance to the South African building sector, Chapter 3 of Brits (2012) can be consulted.

The end-of-life model proposed by Brits was developed to coincide with the pre-use model developed by Brewis. Therefore the same environmental indicators were considered. However, an additional environmental impact, namely Eutrophication Potential, was added as a part of the Emissions environmental indicator. This additional EI did not play a significant role in the pre-use phase, but is an important factor to consider during the end-of-life phase. Eutrophication Potential was also added to the pre-use phase model, in order to ensure consistency across the LCA.

A brief summary of each indicator and its analysis approach is included in this study for clarity.

3.3.1. The Basis of All the End-of-Life Calculations

The most important factor in the calculations for the end-of-life phase is the method of disposal. There are three modelling options when using the ecoinvent database:

1. Direct Recycling
2. Partial Recycling After Sorting
3. Disposal Without Recycling (To Landfill)

This choice must be made for each process included in the analyses. However, this choice will only influence the related impact factors, and not the actual method of calculating the Environmental Impacts.

3.3.2. Emissions

Carbon Footprint (EI_1) and Acidification Potential (EI_2) were calculated in the exact same manner as for the pre-use phase (see Section 3.2.1). The Eutrophication Potential (EI_3), measured in kg NO_{3e}, was calculated in a similar manner:

$$EI_3 = EP = \sum_{i=1}^{n} k_i E_i \tag{10}$$

Where E_i is the amount of a specific gas, as calculated with Equation (2)

k_i is the eutrophication factor (Table 3-3)

TABLE 3-3: EUTROPHICATION POTENTIAL FACTORS (HEIJUNGS *ET AL.*, 1992)

Chemical Formula	Eutrophication Factor [kg NO_{3e}/kg]
NO_x	1.35
NH_3	3.64
NH_4^+	3.6
NO_3^-	1
PO_4^{3-}	10.45
P_2O_5	14.09

Emission factors for this impact category are obtained from the EDIP'97 method on the ecoinvent database. NB: The k_i factor is already brought into calculation by the EDIP'97 method, and therefore the e_i factor obtained from ecoinvent is in the form of kg NO_{3e}/unit of process.

3.3.3. Resource Depletion

This environmental indicator was calculated in the same way as for the pre-use phase (see Section 3.2.2).

3.3.4. Waste Generation

There is only one calculation for waste generation, as there is only one process during the end-of-life phase. This will be calculated in a similar manner as the calculation for production waste in the pre-use phase:

$$Waste\ Generation\ [kg] = waste\ disposal\ factor \times amount\ of\ process \tag{11}$$

Waste disposal factors for this impact category are obtained from the EDIP'97 method on the ecoinvent database. These factors are measured as kg waste per unit of process.

3.3.5. Proposed Environmental Impact Index

The EII was approached in the same manner that was suggested in the pre-use phase model.

Chapter 4: THE USE PHASE

In order to complete the proposed environmental life cycle assessment, a method for the modelling of the use phase was developed. This was then combined with the pre-use and end-of-life phases to perform an analysis of the entire lifespan of a building. This chapter explains how the use phase was quantified for inclusion in the proposed environmental LCA.

4.1. THE SCOPE

4.1.1. THE BUILDING

The scope of the use phase remained the same as for the other phases discussed in Chapter 3. This included all outcomes and factors related to the building envelope, defined as:

- Foundation
- Floor
- External Walls
- Internal Walls
- Ceiling Insulation
- Roofing and Roof Covering

4.1.2. THE IMPACT INDICATORS

The final set of impact indicators that was used for all three phases of the life cycle assessment is summarised here in Table 4-1. The table also indicates the relevant normalisation and weighting factors (Stranddorf *et al.*, 2005 & Goedkoop *et al.*, 2008). No additional EI categories have been added with the development of the use phase, as the use phase covers the same scope and processes as the pre-use and end-of-life phases, with regard to the physical structure and its materials.

TABLE 4-1: SUMMARY OF ENVIRONMENTAL IMPACTS

	EI Name	EI Unit	Normalisation Factor (EDIP'97)	Weighting Factor (EDIP'97)	Origin
EI_1	Carbon Footprint	kg CO_{2e}	8700 kg CO_{2e}/capita/yr	1.12	Global
EI_2	Acidification Potential	kg SO_{2e}	59 kg SO_{2e}/capita/yr	1.27	Europe
EI_3	Eutrophication Potential	kg NO_{3e}	95 kg NO_{3e}/capita/yr	1.22	Europe
EI_4	Resource Depletion	MJ_{ex}			
EI_5	Waste Generation	kg	1350 kg/capita/yr	1.1	Denmark

4.2. DEFINITION

The basic life cycle of a building (as illustrated in Figure 3-1) shows that the use phase can be divided into two main analysis categories: maintenance and operation (Wang *et al*, 2005). It is these two categories that were used to create the use phase of the life cycle assessment.

One of the other major defining characteristics of the use phase is the design life of the building. The National Department of Housing (RSA, 2003:9) stipulates that the minimum design working life (DWL) of a house should be 30 years. This was the base assumption that was applied to this LCA. However, the impact of an increased design working life was considered in a sensitivity analysis.

4.3. MAINTENANCE

The National Department of Housing (RSA, 2003:9) requires that repairable or replaceable components and materials have a minimum design working life of 15 years. Specified items listed include claddings, roofing materials and exterior trims.

Within the scope of this project, the following components were subject to a 15-year maintenance period:

- Plaster and/or other repairable components on walls
- Ceiling and thermal insulation
- Roof covering

For a building with a 30-year design working life this means that maintenance will take place once in the use phase.

Analysing the environmental impact of the maintenance required the combination of the pre-use phase method and the end-of-life method. The components that were replaced were analysed in an end-of-life capacity (as per Brits' model in Section 3.3). The new components which were installed were analysed in a pre-use capacity (as per Brewis' model in Section 3.2).

4.4. OPERATION

Analysing the environmental impact of the building envelope in terms of operation thereof was more difficult, as there is no straightforward approach as with the maintenance.

In a study about LCA for dwellings conducted by Ortiz *et al.* (2007:31) it was found that the greatest environmental impact occurs during the use phase, and that 85% of the energy use occurs during the occupation period of the dwelling. The study also directly links the impact on energy consumption to the impact on the use phase, thereby confirming its prominent influence on the use phase (Ortiz *et al.*, 2007:32). It was therefore decided to use the energy consumption as the measure of the environmental impact of the operation component of the use phase.

4.4.1. ENERGY USE IN SOUTH AFRICAN HOUSEHOLDS

The General Household Survey (GHS) volume which focuses on the topic of energy (Lehohla, 2013) highlights the following four categories of energy usage as important:

- Cooking
- Space heating
- Heating water
- Lighting

According to Ortiz *et al.* (2007:36) the use phase is critical due to the great requirement of energy related to HVAC (Heating, Ventilating, and Air Conditioning), lighting, and heating water (with specific reference to the European context). However, when defining the use phase of the building life cycle, the only activities that are stated to be involved are rehabilitation, repair, maintenance, and service life for HVAC.

It is therefore assumed that the use of energy related to cooking, lighting and heating water would not change in direct response to changes in a building's structure. There can be exceptions, for example a skylight can reduce the need for lighting during daylight hours. These exceptions are, however, uncommon.

It is the category of space heating which is most consistently and obviously impacted by the building envelope itself. Space heating is influenced by the thermal environment inside a building, which is in turn determined by the thermal performance of the building envelope (Ucar & Balo, 2009:88). Al-Homoud (2004:355) also highlights the many benefits of proper thermal insulation in buildings, including economic, environmental, and thermal comfort benefits.

Therefore the use of energy related to space heating was used to calculate the environmental impact of the operation category of the use phase.

4.4.2. Space Heating

In order to quantify the use of energy through space heating, the way in which energy can be used for space heating must first be defined.

There are three main ways in which space heating can occur:

1. Natural Ventilation (also known as passive ventilation)
2. Mechanical Ventilation
3. Mixed mode (combination of natural and mechanical ventilation)

Natural ventilation does not require any energy and therefore does not contribute to the use phase of a building.

Mixed mode buildings do contribute to the energy usage during the use phase, but it is an unpredictable situation that is near-impossible to model accurately. The only way to generate accurate results would be to use real, measured data.

This leaves only mechanical ventilation as a reasonable and useful modelling option.

4.4.3. Mechanical Ventilation

Mechanical ventilation can take many different forms. However, irrespective of the means used for mechanical ventilation, there are two ways in which it can be used: variable or fixed.

4.4.3.1. Variable Ventilation

When mechanical ventilation is not fixed, the use thereof is driven by people's perception of their own thermal comfort.

According to the ANSI/ASHRAE[5] Standard 55 there are six factors when considering thermal comfort:

1. Metabolic Rate
2. Clothing Insulation
3. Air Temperature
4. Radiant Temperature
5. Air Speed
6. Humidity

The first two factors can vary substantially depending on the person that is taken into consideration. Factors 3 through 6 are dependent on the climatic region.

Standard 55 offers methods with which to calculate acceptable thermal comfort regions, but these regions are based on singular input values and only reflect the comfort region related to those specific input values.

[5] ANSI/ASHRAE - American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers

It is not impossible to model, but not very useful as this will most likely not reflect the reality of the situation. If more than one person is able to control the ventilation in a space designed according to one specific person's atmosphere and needs, the reality will deviate from the design.

Another aspect to consider is that of the rebound effect. If a space is optimised for energy efficiency in terms of space heating (for example by designing the space for optimal thermal comfort) there is a chance of a considerable rebound effect.

A simple example of the rebound effect: High energy consumption leads to energy efficient measures being put in place. This causes a reduction in energy consumption. The consumer, aware of their saving due to the lowered energy consumption, finds it acceptable to use more energy, and thus causes a rebound effect.

According to a summary of results by Greening *et al*. (2000:398) the potential size of rebound on a 100% increase of energy efficiency in space heating is 10 to 30%.

Even though there are existing calculations and analysis methods that can aid in estimating the results of variable ventilation, the human factor makes it an unpredictable and most likely unreliable analysis.

4.4.3.2. Fixed Ventilation

Fixed mechanical ventilation is ventilation with the use of an HVAC (heating, ventilating, and air conditioning) system that is set to operate under certain conditions, with minimal manual interference.

This can be accomplished by either having time-dependent ventilation (where there is a set time-schedule with linked temperatures) or temperature-dependent ventilation (where ventilation runs when the room temperature falls outside a prescribed range).

Both of these scenarios can easily be modelled using thermal calculation software.

4.4.4. Method

Part XA of the SANS 10400 Code gives clear guidelines for calculating the energy usage with regards to the ventilation in a building. The following prescribed guidelines were accepted as standard for the calculation of the environmental impact of the operation category of the use phase (SANS, 2011c:8):

1. The space temperature must remain within the range of 19°C to 25°C for 98% of the operation time.
2. The design calculations must be done with the approved climatic data provided by Agrément SA.
3. Certified thermal calculation software must be used.

4.4.4.1. Agrément SA

Agrément SA provides climatic data for six regions in South Africa, with reference to a specific city in that climatic region:

1. Climate Region 1 (Johannesburg)
2. Climate Region 2 (Pretoria)
3. Climate Region 3 (Musina)
4. Climate Region 4 (Cape Town)
5. Climate Region 5 (Durban)
6. Climate Region 6 (Upington)

This data has been compiled to represent the climate of each region for a typical design year. With only six different climate scenarios, there are many uncertainties and limitations to the design, but currently it is a requirement of Part XA that this data be used. When calculating data for the LCA it is important to choose the climate region that corresponds to the climate region where your building is located, as the climate is an essential factor in the thermal energy calculations.

4.4.4.2. DesignBuilder

There are currently only three thermal calculation software programs that are certified for use in South Africa:

- BSIMAC (Version 9) Building Energy Analysis Software [Agrément Certificate 2012/412]
- DesignBuilder (Version 3.1) Building Energy Analysis Software [Agrément Certificate 2012/413]
- IES Virtual Environment Software (Version VE 2013) [Agrément Certificate 2013/444]

BSIMAC was immediately excluded as an option, as it did not have a graphical user interface. Both DesignBuilder and IES would be acceptable options for the necessary calculations. While IES is more powerful than DesignBuilder, it is also trickier and requires more skill to use. DesignBuilder allows for the modelling of complex structures through a simple, user-friendly interface. It was therefore decided that DesignBuilder would be used for the thermal calculations necessary for the LCA.

Analysing the building with this software gives a result for the annual energy consumption for both heating and cooling.

$$AEC_A = AEC_H + AEC_C \tag{12}$$

Where AEC_A is the energy consumption that is influenced by the building envelope for one year [kWh]

Multiplying this value by the DWL (length of the use phase, in years) gives the total energy consumption for the operation category of the use phase:

$$AEC = AEC_A \times DWL \tag{13}$$

This AEC value can then be added to the analysis sheet in the same way as the building materials. The ecoinvent process that is used to obtain environmental factors for the AEC is “electricity production, hard coal, ZA”. This provides environmental factors for electricity generated in an average hard coal power plant in South Africa. All impact factors are expressed as an impact per 1 kWh of electricity generated.

The choice of this specific ecoinvent process was made due to the statistics regarding energy production in South Africa listed in Section 2.2.

Chapter 5: Application of the Environmental Life Cycle Assessment Tool

The aim of this chapter is to introduce the reference design building model that was used in the application of the proposed environmental LCA tool. It clarifies all constant design assumptions, and introduces the reference design external wall, which was used to show the capacity of the proposed LCA as an analysis tool. This chapter also introduces the eight alternative external wall designs which were used as the variable factor in an optimisation study (again with the use of the proposed LCA).

5.1. Location

As this study is dependent on the use of energy calculations, the choice of location was restricted to one of the six options which are included in the approved weather data provided by Agrément SA. These six options each represent a climatic region from Part XA, but offers specific climate data from a city within that climatic region. Although it is acceptable to use that specific city data as representative for any location within the same climatic region, it would more accurately reflect the data from that specific city.

It was therefore decided to use one of the representative cities. For this study the chosen city was Cape Town.

It is important to note that as the operations component of the use phase is highly dependent on the climate situation, the outcome can be different depending on the region. A simple sensitivity analysis to consider this fact is included in Chapter 8.

5.2. Choice of Building

5.2.1. The Distribution

Statistical data used in this section was compiled mostly from the General Household Survey (hvac) of 2002-2012. This provides data from several different viewpoints by giving statistics on not only a national scale, but also on a provincial scale, as well as by income quintile. As the chosen location, Cape Town, is located in the Western Cape, provincial data specific to the Western Cape was also considered.

The margins of the income quintiles are determined on a national level, by number of households. For example, the 20% of households with the lowest incomes form Quintile 1 and determine the quintile income bracket. The distribution of quintiles for 2012 can be found in Table 5-1.

TABLE 5-1: INCOME QUINTILES [SOUTH AFRICA, 2012]

	Per Capita Monthly Household Income Bracket	Number of Households (thousands)	Percentage of Households
Quintile 1	R0 to R390	2926.2	20%
Quintile 2	R391 to R764	2926.2	20%
Quintile 3	R765 to R1499	2926.2	20%
Quintile 4	R1500 to R3997	2926.2	20%
Quintile 5	R3997 and higher	2926.2	20%
TOTAL		**14631**	**100%**

The national definitions of the quintiles are then used to calculate data on a provincial level. Therefore the provincial quintiles are defined by the nationally-determined income brackets and not by the number of households.

The quintile distribution for the Western Cape can be found in Table 5-2.

TABLE 5-2: INCOME QUINTILES [WESTERN CAPE, SOUTH AFRICA, 2012]

	Per Capita Monthly Household Income Bracket	Number of Households (thousands)	Percentage of Households
Quintile 1	R0 to R390	436	12.1%
Quintile 2	R391 to R764	385	16.2%
Quintile 3	R765 to R1499	342	21.1%
Quintile 4	R1500 to R3997	262	23.8%
Quintile 5	R3997 and higher	196	26.9%
TOTAL[6]		**1621**	**100.1%**

5.2.2. Space Heating

As discussed in Section 4.4, the operation component of the use phase can be predicted most accurately when space heating is provided through consistent mechanical ventilation. It is therefore prudent to identify the type of households in South Africa that this applies to.

Figure 5-1 illustrates the percentage of households in each income quintile that has air conditioners. According to these figures, nearly a fifth of households in the wealthiest quintile have air conditioners. It would therefore be useful to model a household that falls within this income quintile.

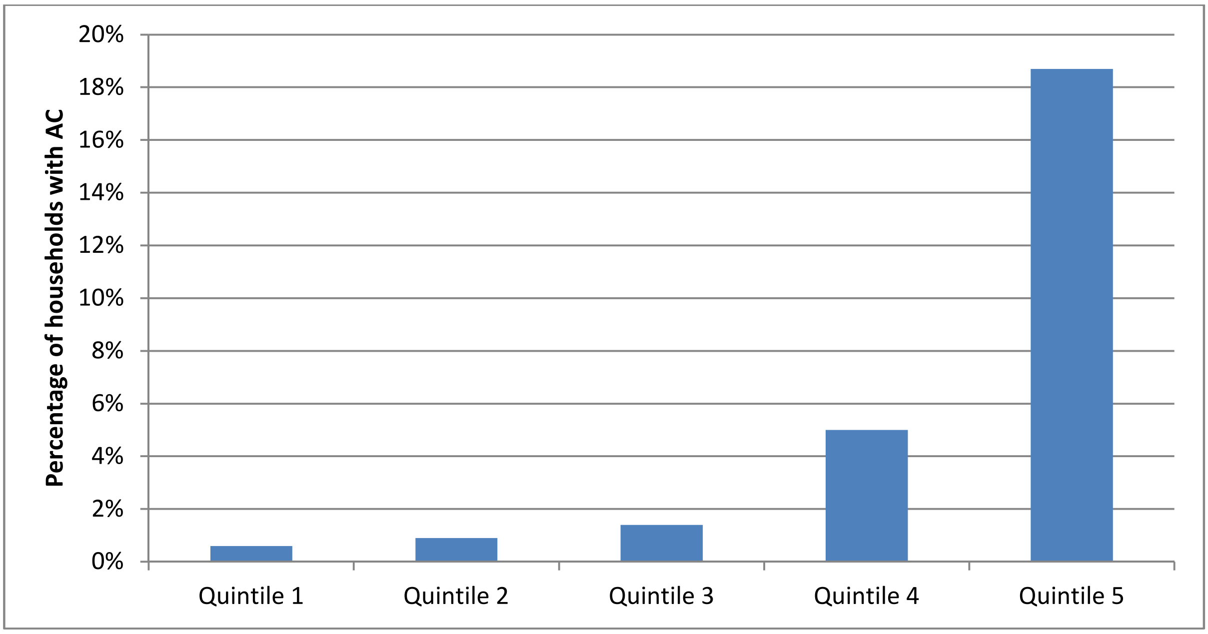


FIGURE 5-1: PERCENTAGE OF HOUSEHOLDS WITH AIR CONDITIONERS [SOUTH AFRICA, 2012]

[6] Percentages were taken directly from the GHS; the number of households was calculated with the rounding error included, which explains why the 'Total Number of Households' is slightly higher than the real value.

5.2.3. Proposed Size

The average household sizes in South Africa and the Western Cape are 3.7 and 3.6 respectively (Lehohla, 2013:15). Therefore the number of people in the household was chosen as four. The chosen assumption was that this represents a family household. Two income cases were also considered:

1. One adult earns 100% of the household income.
2. Two adults each earn 50% of the household income.

These cases were specifically chosen in order to represent the opposite ends of the income tax bracket, which is needed to determine the household's disposable income.

Using this household size in conjunction with the minimum per capita monthly household income for Quintile 5, a calculation was made to determine the price of the house that could be afforded by one such household. The summary of the results can be seen in Table 5-3, while the full calculation can be found in Appendix A1.

TABLE 5-3: MONTHLY MORTGAGE PAYMENT (MINIMUM IN QUINTILE 5)

	Income Case 1	Income Case 2
Monthly Household Income	R 15 988.00	R 15 988.00
Monthly Household Disposable Income	R 13 920.99	R 15 071.28
Monthly Mortgage Payment	R 5 220.37	R 5 651.73

Using the maximum possible value, in this case a monthly mortgage of R5 651.73, several South African banks were consulted to determine the possible value of a house with the calculated monthly mortgage.

The values in Table 5-4 were determined on the following conditions:

- No deposit
- Interest rate: 9.25% (current rate)
- Bond term: 25 years/300 months

Printouts of these calculations can be found in Appendix A2.

TABLE 5-4: CALCULATED HOME LOAN AMOUNTS

	Absa	Nedbank	Standard Bank
Monthly Repayment	R 5 652.12	R5 6520.00	R 5 651.73
Home Loan Amount	R 660 000.00	R 660 000.00	R 659 954.44

According to the Absa house price indices published at the start of 2013, the nominal average value of a home sized between 80m^2 and 140m^2 is R 791 100.00. Comparing this value to the home loan amounts calculated in Table 5-4, it would be a reasonable assumption that households in Quintiles 1 to 4 would be unable to afford a middle-segment home of this size.

The chosen size for the application home must therefore be more than 80m^2.

5.2.4. Proposed Layout & Dimensions

An original layout was designed for this application home by studying recent property developments in the Cape Town and Western Cape area, as well as considering basic restrictions provided by the National Home Builders Registration Council (NHBRC) and the SANS 10400.

The proposed layout can be seen in Figure 5-2 (with an enlarged version in Appendix A3) and has a footprint of 91m^2. It is a three-bedroom home with one and a half bathrooms, a living room, a dining room, and a kitchen. The width of the building was chosen as 7m, which complies with the restriction that a maximum clear span of 8m is allowed for a Howe truss roof, as per SANS 10400-L (2011b:23). A list of basic dimensions for the proposed building can also be found in Appendix A4.

The proposed layout assumed the basic design principles which are discussed further in the following sections. This assumed internal walls at a width of 90mm and external walls at a width of 140mm.

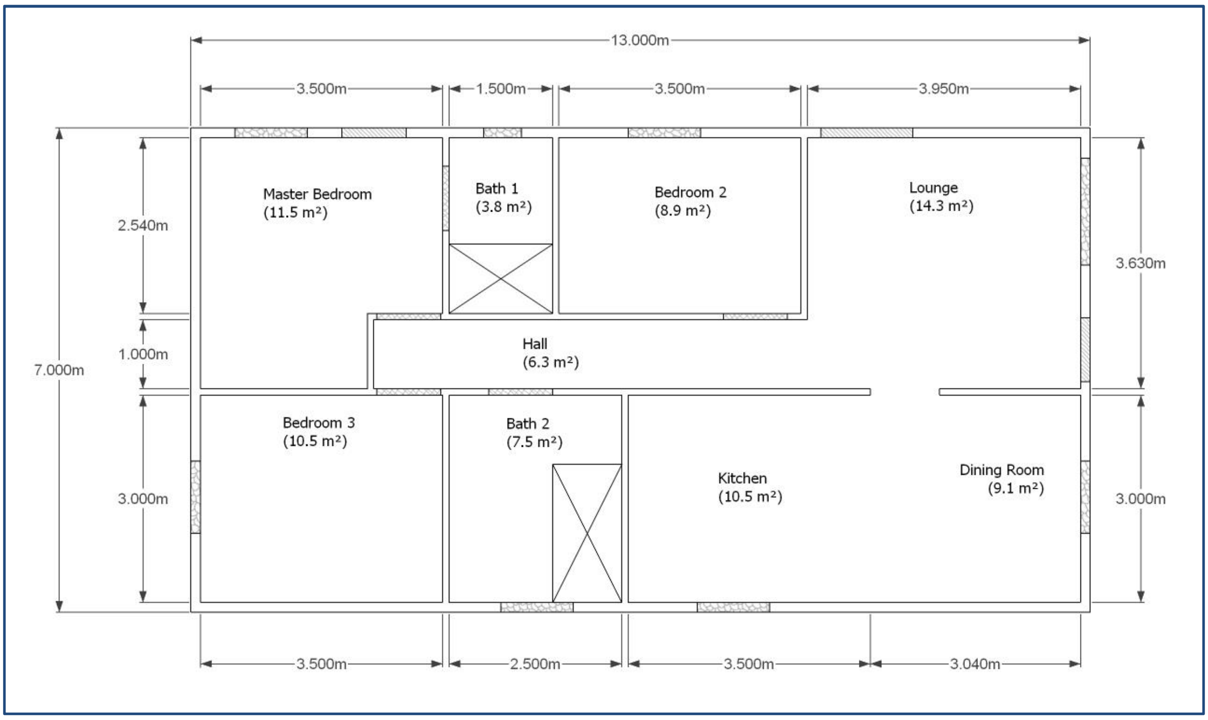


FIGURE 5-2: PROPOSED LAYOUT

In order to calculate comparable results, the building footprint must be the same for each individual case study. As the wall thickness can differ depending on the type of wall construction used in each case study, the following basic principles were applied:

1. The outside perimeter was kept the same for each building.
2. The distances from the outside of the external walls to the centres of the internal walls remained the same. In other words the internal walls remained in the exact same positions with respect to the external perimeter, irrespective of the external wall thickness.

As the wall thickness increases, the volume of each room will decrease slightly. The volume of the room is important when calculating the energy needed to heat or cool the space. However, this small change in room volume can be assumed as having a negligible impact on the energy usage, according to Hugo (2014).

5.2.5. Structural Components

All structural components of the building were fixed-design components that comply with minimum SANS 10400-XA standards. The only variable component (which is used to show the capability of the proposed LCA as an optimisation tool) was the external wall construction.

5.2.5.1. Foundation and Floor Slab

The foundation and floor slab were designed in accordance with SANS 10400-H. It was designed as a basic strip foundation with thickened footings (SANS, 2012a:18).

From Table 7 (SANS, 2012a:17) it was chosen that the width of the strip footings *w* be equal to 400mm. The following components were included in the calculations, using basic measurements from the proposed design:

Foundation

- Concrete for thickened floor areas underneath internal walls (walls which only support their own weight)
- 4xY12 reinforcing steel bars in the thickened floor areas
- Foundation walls (from natural ground level to strip footings) – 140mm solid concrete masonry blocks
- Strip footings (400x210mm)

Floor Slab

- 250 micron polyolefin membrane (assumed polyethylene)
- 100mm reinforced concrete slab
- Steel mesh (fabric ref. 193) with 5.6mm diameter bars at 200mm centres in both directions

All dimensions for calculations relating to external walls were calculated on the length of the outside perimeter, in order to deliver a conservative result.

SANS 10400-XA only has specific requirements regarding floors with underfloor heating, and therefore the foundation and floor slab were simply designed to standard, as prescribed above.

5.2.5.2. Internal Walls

All internal walls were assumed to be 90mm single leaf concrete block walls, plastered on both sides. SANS 10400-XA has no specific requirements regarding internal walls and these can therefore be chosen at the designer's own discretion.

5.2.5.3. Ceiling and Thermal Insulation

A standard thermal insulation combination that is used in South African housing consists of:

- 6.4mm gypsum plaster board
- 50mm glass wool

However, this does not meet the specified minimum R-value as prescribed by SANS 10400-XA. The decision was made to keep the same materials, but increase the thickness of the glass wool in order to reach the required R-value of 3.7. The thermal insulation was thus chosen as:

- 6.4mm gypsum plaster board
- 145mm glass wool

5.2.5.4. Roofing

The roofing was designed in accordance with SANS 10400-L. It was designed as a six-bay Howe truss, as a clear span of 7m is required (a four-bay Howe truss allows a maximum clear span of 6m). An overhang of 200mm was chosen.

The following recommendations were chosen from Table 4 (SANS, 2011b:24):

- Roof pitch: 17.5 degrees
- Maximum centre-to-centre truss spacing: 1200mm

TABLE 5-5: MEMBER SPECIFICATIONS FOR HOWE ROOF TRUSS (SANS, 2011B:24)

	Size (mm)	Grade	Thickness (mm)
Top chord/Rafter	114	5	38
Bottom chord/Beam	152	5	38
Web	114	5	38

Calculations yielded a volume of 0.1109m^3 for each Howe truss with the above specifications. For the proposed home (with a length of 13m) a minimum of 11 trusses were required.

The following components were included in the final calculations:

- Six-bay Howe truss
- 50mm x 76mm purlins
- 38mm x 114mm wall plates

This structural component does not contribute to the thermal insulation of the roof, and therefore does not have any requirements in terms of SANS 10400-XA.

5.2.5.5. Roof Covering

The roof covering was considered in conjunction with the ceiling and thermal insulation to determine the R-value of the roof. The following roof covering was used with the thermal insulation specified above to reach the required minimum R-value of 3.7:

- 0.54mm zincalume-based steel sheeting
- Galvanised steel ridge cappings (450mm girth)

This steel sheeting is not galvanised with a normal zinc coating, but rather with a zinc/aluminium alloy. Manufacturers contend that this type of product is more durable and sustainable than regular galvanised steel. A Zincalume steel brochure (New Zealand Steel, 2010:4) shows how Zincalume sheeting outperforms galvanised sheeting in severe, industrial, and moderate coastal areas (such as Cape Town). The data, gathered from international test sites, shows that the estimated life ("years to perforation") of galvanised steel is about 30 years, while Zincalume-coated steel lasts about 40 years.

5.2.5.6. Openings

This section studies all the doors and windows. These are considered to be finishes to the building, and have been excluded from the proposed LCA. However, they are still important to the calculations in two main ways:

1. The openings provided for these finishes decrease the internal and external wall areas.
2. The openings and their construction play a role in the thermal performance of the building.

All openings were chosen to fit to standard regulations, as well as to comply with the regulation in Part XA which requires total fenestration to be a maximum of 15% of the net floor area.

Sizes of opening areas were chosen from products by Swartland, a South African provider of doors and windows that complies with all the latest South African Bureau of Standards (SABS) standards regarding these products. A full list of the fenestration and opening sizes and calculations can be found in Appendix A5.

In compliance with SANS 10400-N (2012b:12) all windows were installed at a top height of 2.1m, to ensure that no windows required safety glazing (which is compulsory for the first 0.5m from floor height).

5.2.5.7. External Walls

This section will only discuss the properties of the external walls for the reference building design. These external walls must comply with the restriction set out in Part XA (SANS, 2011c:10), summarised in Table 5-6. The proposed external wall construction for the reference building was based on a typical construction seen in South African housing.

TABLE 5-6: MINIMUM R-VALUE REQUIREMENTS (SANS, 2011C:10)

Type of external wall	Minimum R-value
Masonry	0.35
Non-masonry (Climatic zones 1 & 6)	2.20
Non-masonry (Climatic zones 2, 3, 4 & 5)	1.90

The following components were considered:

- 375 micron damp-proof course (DPC)
- Plastered externally (12mm)
- 140mm hollow concrete masonry blocks, single leaf
- Concrete fill for top two courses of blockwork
- Plastered internally (12mm)
- Galvanised brickforce, per the NHBRC (at 400mm distances)

This design meets the minimum requirement for the R-value of an external masonry wall in Part XA (SANS, 2011c:10), which is currently set at 0.35.

A 3D representation of this layout design can be seen in Figure 5-3, while a set of eight alternative external walling designs are discussed in the following section.

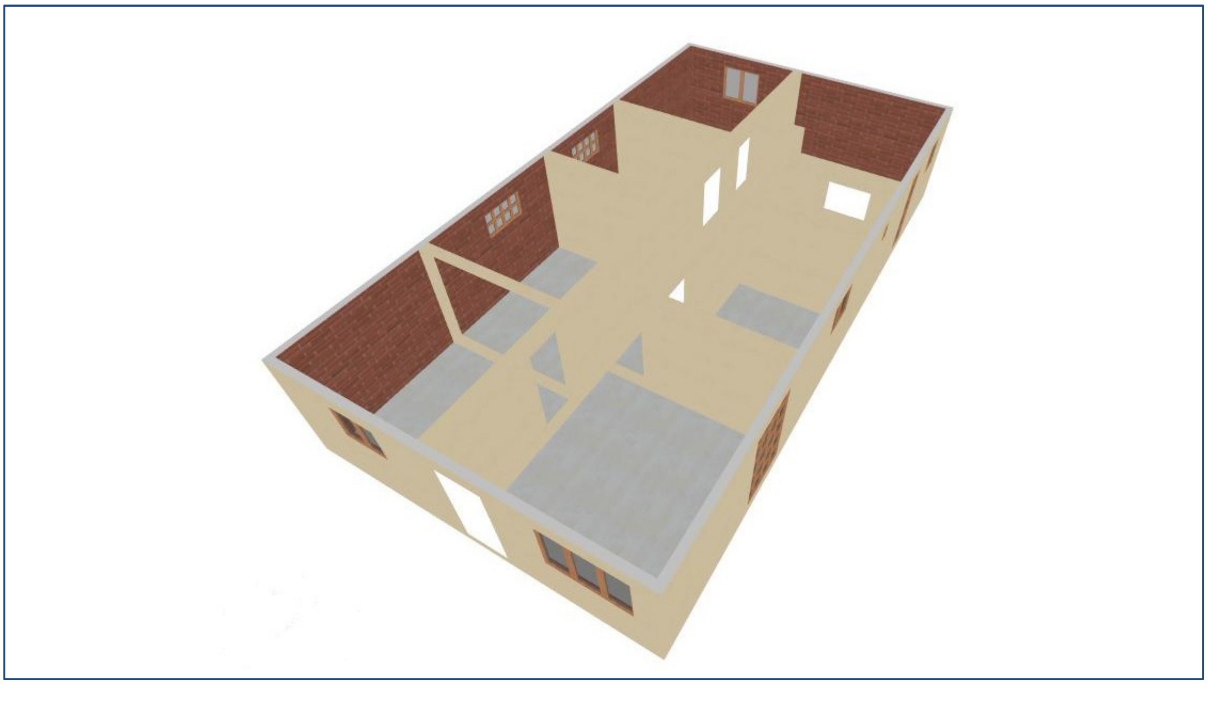


FIGURE 5-3: 3D LAYOUT OF PROPOSED REFERENCE BUILDING

5.3. Alternative External Wall Designs

As part of the demonstration of the environmental LCA as an optimisation tool, the reference design was modified by changing the external wall construction. In order to obtain an accurate result concerning the changes caused by the change in external wall construction, it must be the only variable.

Therefore an important note must be made: this study *does not verify* the structural stability of these designs. The first two variations are common masonry constructions and the third is a cast concrete wall, but the other five variations are the external walling constructions of Agrément SA-approved building systems.

Most of these building systems contain their own roofing and foundation systems, which are the systems that are approved for use with the specified walling systems. For the purpose of this study, *only* the external walling systems were varied—the roofing system, the foundation system, and all other building components are kept constant, as described for the reference building design.

Below is a short description of each external walling system, while a complete data sheet for each walling system has been included in Appendix B. All R-values were calculated with the use of DesignBuilder.

5.3.1. External Wall Design 1: Reference Building

This is the single leaf hollow concrete masonry design which is described in section 5.2.5.7 and was used as a reference for comparison for the other external wall designs.

5.3.2. External Wall Design 2: Single Leaf Clay Masonry

This wall design is another widely-used wall construction in South Africa. This specific design consists of:

- 375 micron DPC
- Plastered externally (12mm)
- 140mm solid clay masonry blocks, single leaf
- Plastered internally (12mm)
- Galvanised brickforce, per the NHBRC (at 400mm distances)

This external wall design has an R-value of 0.412, which complies with the values set out in Table 5-6.

5.3.3. External Wall Design 3: Double Leaf Brick Cavity Wall

This wall design is a basic double leaf clay brick cavity wall with 12mm plaster on either side that consists of:

- 375 micron DPC
- Plastered externally (12mm)
- 90mm solid clay masonry blocks, two layers separated by a 50mm air cavity
- Plastered internally (12mm)
- Galvanised brickforce, per the NHBRC (at 400mm distances)

This external wall design has an R-value of 0.648, which complies with the values set out in Table 5-6.

5.3.4. External Wall Design 4: Cast Concrete Wall

This wall design is a basic cast concrete wall with 12mm plaster on either side that consists of:

- 375 micron DPC
- Plastered externally (12mm)
- 200mm cast concrete
- Plastered internally (12mm)

This external wall design has an R-value of 0.361, and as such does not comply with the non-masonry values set out in Table 5-6.

5.3.5. External Wall Design 5: Innovida Building System

This wall design is the first of five Agrément SA-approved alternative walling system that was considered in this study. It consists of an expanded polyurethane core encapsulated by two sheets of resin-saturated glass fibre. The following items were included in the LCA:

- 375 micron DPC
- 60mm expanded polyurethane (EPU)
- 2mm resin-saturated glass fibre sheet (both internal and external)
- 70x60x2mm glass fibre base rail

This external wall design has an R-value of 2.89, and as such complies with the non-masonry values set out in Table 5-6.

5.3.6. External Wall Design 6: Affordable Comfort Homes

This wall design is an Agrément SA-approved alternative walling systems that consists of two sheets of galvanised sheet steel encapsulating an EPU core, with Rhinowall internal cladding. The following items were included in the LCA:

- 375 micron DPC
- 60mm expanded polyurethane (EPU)
- 0.6mm galvanised sheet steel (both internal and external)
- 15mm gypsum plasterboard (internal)
- 52x52x2mm galvanised steel base rail

This external wall design has an R-value of 2.839, and as such complies with the non-masonry values set out in Table 5-6.

5.3.7. External Wall Design 7: MG Sip Building System

This wall design is an Agrément SA-approved alternative walling system and consists of a polyurethane core encapsulated by two layers of thick oriented strand board (OSB), clad internally with gypsum plasterboard and externally with medium density Nutek board. The following items were included in the LCA:

- 375 micron DPC
- 103mm EPU
- 15mm gypsum plasterboard (internal)
- 12mm fibre-cement board (external)
- 11mm OSB (both internal and external)
- 127x52x2mm steel base rail
- 38x38mm timber brandering, at 300mm centres (both sides)

This external wall design has an R-value of 4.957, and as such complies with the non-masonry values set out in Table 5-6.

5.3.8. External Wall Design 8: Blast Building System

This wall design is an Agrément SA-approved alternative walling system and consists of a thick sprayed concrete wall with internal magboard cladding and external plaster rendering. The following items were included in the LCA:

- 375 micron DPC
- 90mm thick sprayed concrete
- 50x50x2.5mm weldmesh
- 6mm magboard (internal)
- 15mm plaster (external)
- 92x40x1.5mm zincalume base rail & channel at top

This external wall design has an R-value of 0.278, and as such does not comply with the non-masonry values set out in Table 5-6.

5.3.9. External Wall Design 9: Ikhaya Future House Building System

This was the final external wall design and is also an Agrément SA-approved alternative walling system. It consists of an expanded polystyrene (EPS) core surrounded by galvanised weldmesh and plaster. The following items were included in the LCA:

- 375 micron DPC
- 80mm EPS
- 100x100x3.5mm galvanised steel weldmesh (on both sides)
- 40mm plaster (both internal and external)

This external wall design has an R-value of 2.33, and as such complies with the non-masonry values set out in Table 5-6.

5.4. General Design Assumptions

These general design assumptions include, where applicable, assumptions made by both Brewis (2011:44) and Brits (2012:53).

5.4.1. Materials

- Zincalume is not yet an available option in the ecoinvent database. As such, the zincalume sheet steel in calculations was assumed equivalent to galvanised sheet steel.
- Mortar and plaster is not available in the ecoinvent database. As suggested by Brewis (2011:44) this was represented by a cement-to-sand ratio of 4:1.
- Galvanised and zincalume steel was considered in the same manner as regular steel during the end-of-life phase.

5.4.2. Quantities

- Many of the external wall systems are limiting in the sense that they are only available in certain panel sizes. This was ignored, and quantities for all external wall materials were only calculated in terms of the actual wall volume represented in the proposed design.
- Quantities for the different materials in the external walls were calculated with respect to the outer perimeter of the exterior wall, irrespective of the position of the layer within the wall.
- If the wall width increases (through the use of different external walling systems), the net floor area of the building decreases slightly. This effect was assumed to be negligible.

5.4.3. Transport

- A truck sized 3.5 – 7.5t was selected for transport purposes. The standard of the truck was assumed to be EURO3 (from options EURO3 to EURO6) as this is the type of truck with the worst emission rates, and is most representative of the trucks used in South Africa.

- Additional transport of 100km to the construction site was included for all materials. This is to compensate for the larger travelling distances as discussed by Brewis (2011:44).
- Similarly, additional transport of 10km to the landfill/recycling site was added for all waste materials (Brits, 2012:53). This included the generated construction waste.

5.4.4. Life Cycle

- The DWL was assumed to be 30 years.
- The maintenance period was assumed to be 15 years, irrespective of the difference in durability of the materials included in the maintenance section.
- It is important to note that both these assumptions were chosen, as with the individual component designs, to comply with the minimum regulations as set out in the SANS codes. These are not necessarily realistic values, but they do meet the minimum requirements.

5.4.5. Waste

- At the end of its use, all materials were assumed to go to final disposal (either at a landfill or to incineration). There were a small number of exceptions, due to the restriction of data availability.
- All brickforce was assumed to be transported to a sorting plant.
- Waste gypsum was assumed to be transported to a sanitary landfill.
- The amount of waste to be transported at disposal equalled the total mass of materials that one building consists of.

5.4.6. ecoinvent

- Version 3.1 of the ecoinvent database, which was released in 2014, was used for all calculations.
- The chosen system model for data retrieval was “Allocation, ecoinvent default”.
- Wherever possible, factors for location RoW (rest of the world) were used. This is generalised data that can be used when no region-specific data is available, for countries outside Europe (as there is a factor RER for countries within Europe).
- For disposal, there were many processes that did not have a RoW factor. In these cases, factors for the location CH (Switzerland) were used, as this has the most extensive range of data available on ecoinvent.
- The ZA (South Africa) factors were used for the factors pertaining to electricity generation. This is due to the fact that the electricity generation contributes the dominant portion of the first four environmental impacts over the whole life cycle, and it is therefore important that an accurate representation is used.

5.4.7. DesignBuilder

- Even though a newer version is available, Version 3.1.0.036 was used as it has been approved for use with the SANS 10400-XA code by Agrément SA. Version 4.2.0.054 has been submitted for approval, but it has not received approval at this stage (Joubert, 2014).
- Section 5.5 gives a detailed account of all DesignBuilder setup choices and assumptions that were made to model the reference building.

5.5. DesignBuilder Setup and Assumptions

The DesignBuilder setup was done with the help of Greenplan Consultants, the South African company in charge of DesignBuilder distribution and training. They place specific focus on using DesignBuilder for SANS 10400-XA compliance. The details listed below were used as fixed details in all analyses. However, several of the topics are also considered in sensitivity analyses in Chapter 8.

5.5.1. Location

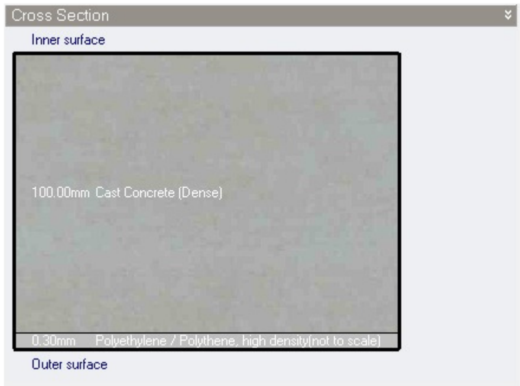
Site Location		
	Cape Town	Latitude (°): -33.98 Longitude (°): 18.60
Site Details		
	Elevation above sea level	42.0m
	Site orientation	The building was orientated in such a way that the longer axis of the building runs in an east/west direction, with the northern side consisting of the rooms where the most time is spent, as per SANS 204 (2011a:7).
Simulation Weather Data		
		The required weather data, as approved and provided by Agrément SA in accordance with the site location (Cape Town), was used.

5.5.2. Activity

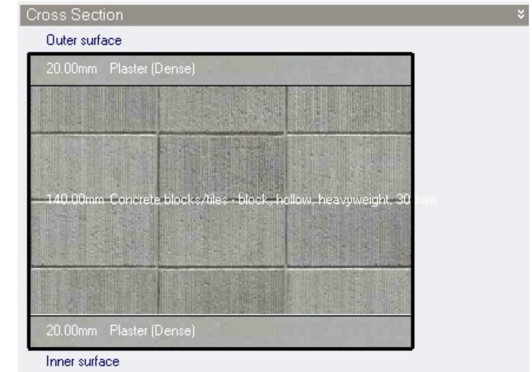
Building Total Floor Areas		
	Occupied floor area	86 m^2
	Unoccupied floor area	91 m^2
Occupancy		
	Density (people/m^2 of occupied floor area)	4/86 = 0.047 people/m^2
	Occupancy schedule	24 hours/day, 7 days/week. This assumption, while inaccurate, is in compliance with SANS 10400-XA. This same schedule was assumed at ALL other points in DesignBuilder setup. A sensitivity analysis was done to determine the impact of this assumption.
	Latent fraction	25%
Metabolic		
	Activity factor	1.00
	Clothing	Winter clothing (clo): 1.00 Summer clothing (clo): 0.50
Environmental Control		
	Heating Setpoint Temperatures	Heating: 19.0°C (As per the minimum acceptable temperature (SANS, 2011c:8).) Heating setback[7]: 12.0°C
	Cooling Setpoint Temperatures	Cooling: 25.0°C (As per the maximum acceptable temperature (SANS, 2011c:8).) Cooling setback[8]: 28.0°C
	Minimum Fresh Air	Fresh air: 10 l/s-person
Other Heating Influences		
	Computers Office Equipment Miscellaneous Catering Process	These have all been marked as “off”. These influences do not contribute significant amounts of heat in a home-setup.

[7] Setback temperatures are obsolete for a 24/7 schedule, but still must be defined.
[8] Setback temperatures are obsolete for a 24/7 schedule, but still must be defined.

5.5.3. CONSTRUCTION

Floors		
	Layers	**Layers** Number of layers: 2 **Outermost layer** Material: Polyethylene / Polythene, hig Thickness (m): 0.0003 ☐ Bridged? **Innermost layer** Material: Cast Concrete (Dense) Thickness (m): 0.1000 ☐ Bridged?
	Image	
	Calculated	**Inner surface** Convective heat transfer coefficient (W... 0.342 Radiative heat transfer coefficient (W/... 5.540 Surface resistance (m2-K/W) 0.170 **Outer surface** Convective heat transfer coefficient (W... 19.870 Radiative heat transfer coefficient (W/... 5.130 Surface resistance (m2-K/W) 0.040 **No Bridging** U-Value surface to surface (W/m2-K) 13.883 R-Value (m2-K/W) 0.282 **U-Value (W/m2-K) 3.546**
Internal Partitions		
	Layers	**Layers** Number of layers: 3 **Outermost layer** Material: Plaster (Dense) Thickness (m): 0.0120 ☐ Bridged? **Layer 2** Material: Concrete Block (Heavyweig Thickness (m): 0.0900 ☐ Bridged? **Innermost layer** Material: Plaster (Dense) Thickness (m): 0.0120 ☐ Bridged?
	Image	

	Calculated	Inner surface Convective heat transfer coefficient (W... 2.152 Radiative heat transfer coefficient (W/... 5.540 Surface resistance (m2-K/W) 0.130 Outer surface Convective heat transfer coefficient (W... 19.870 Radiative heat transfer coefficient (W/... 5.130 Surface resistance (m2-K/W) 0.040 No Bridging U-Value surface to surface (W/m2-K) 9.689 R-Value (m2-K/W) 0.273 **U-Value (W/m2-K) 3.660**
Roof		
	Layers	Layers Number of layers 3 Outermost layer Material Metals - steel Thickness (m) 0.0005 ☐ Bridged? Layer 2 Material Glass wool, 100 mm Thickness (m) 0.1450 ☐ Bridged? Innermost layer Material Gypsum Plasterboard Thickness (m) 0.0064 ☐ Bridged?
	Image	
	Calculated	Inner surface Convective heat transfer coefficient (W... 4.460 Radiative heat transfer coefficient (W/... 5.540 Surface resistance (m2-K/W) 0.100 Outer surface Convective heat transfer coefficient (W... 19.870 Radiative heat transfer coefficient (W/... 5.130 Surface resistance (m2-K/W) 0.040 No Bridging U-Value surface to surface (W/m2-K) 0.274 R-Value (m2-K/W) 3.791 **U-Value (W/m2-K) 0.264**
External Wall (Reference Design)		
	Layers	Layers Number of layers 3 Outermost layer Material Plaster (Dense) Thickness (m) 0.0200 ☐ Bridged? Layer 2 Material Concrete blocks/tiles - block, Thickness (m) 0.1400 ☐ Bridged? Innermost layer Material Plaster (Dense) Thickness (m) 0.0200 ☐ Bridged?

	Image	
	Calculated	**Inner surface** Convective heat transfer coefficient (W... 2.152 Radiative heat transfer coefficient (W/... 5.540 Surface resistance (m2-K/W) 0.130 **Outer surface** Convective heat transfer coefficient (W... 19.870 Radiative heat transfer coefficient (W/... 5.130 Surface resistance (m2-K/W) 0.040 **No Bridging** U-Value surface to surface (W/m2-K) 5.444 R-Value (m2-K/W) 0.354 **U-Value (W/m2-K) 2.827**

5.5.4. Openings

Glazing		
	External Windows	Source SANS 204, Table 6 Category Single Region General **Definition method** Definition method 2-Simple **Simple Definition** Total solar transmission (SHGC) 0.810 Light transmission 0.830 **U-Value (W/m2-K) 5.840**
	Frame and Dividers	Wooden Window Frame

Section 5.2.5.6 details how openings for the reference buildings were selected. These openings were all individually modelled and defined. The front door (on the Eastern wall) was modelled as a normal wooden door, while the two doors on the northern side were modelled as glazing. All windows and "glazing" doors were also individually modelled in terms of number of frame dividers.

5.5.5. Lighting

Lighting generates some consistent heat that may contribute to cooling needs. However, the energy needs for lighting were not taken into account, as discussed in Section 4.4.1.

General Lighting		
	Lighting energy	5.00 W/m^2
	Luminaire type	Suspended
	Radiant fraction	0.420
	Visible fraction	0.180

5.5.6. HVAC

HVAC for the reference design was assumed to be used throughout the entire building, with the only exception being the bathrooms. Also, in accordance with Part XA (SANS, 2011c:8) the HVAC was assigned to be operational for the full time of occupation, which was assumed to be 100%. The HVAC was used to maintain the temperature within the range of 19°C to 25°C, as per SANS standards (2011c:8).

Mechanical Ventilation		
	ON	
	Outside air definition method	Min fresh air (per person)
Heating		
	HEATED	
	Fuel	Electricity from grid
	Heating system CoP	1.000
Cooling		
	COOLED	
	Fuel	Electricity from grid
	Heating system CoP	2.500
Natural Ventilation		
	ON	
	Outside air definition method	By zone
	Outside air (ac/h)	3.000

5.5.7. Simulation

The simulation was run for an annual calculation of a design year, per the chosen climatic data. The simulation was done in steps of four per hour, in other words 15-minute increments.

Although DesignBuilder allows for the users to design their own, detailed HVAC system, this is mainly a function for mechanical engineers. It was therefore decided that the heating and cooling equipment be auto-sized during the simulation process.

Chapter 6: Environmental Life Cycle Assessment as an Analysis Tool

This set of results shows the capacity of this tool for analysing a building, and therefore focusses solely on the reference building, as described in the previous section.

The building was modelled in DesignBuilder to obtain the electricity usage necessary to keep the building within the acceptable temperature range as prescribed in SANS 10400-XA.

FIGURE 6-1: DESIGNBUILDER VISUALISATION OF THE REFERENCE BUILDING

This reference building can also be used to check compliance of any building design with the same footprint.

The calculated energy data (in kWh) was then added to the LCA study, in order to generate the operation component of the use phase.

This section analyses the contributions to individual EI categories, but also considers the building as a whole.

6.1. Carbon Footprint

The importance of the carbon footprint has already been discussed in Section 2.2. It is therefore one of, if not the most important emission categories to be considered.

The full life cycle amounts, generated per phase, can be seen in Figure 6-2. As expected, the electricity usage (which represents the operations component of the use phase) is by far the biggest contributor due to the fact that electricity generation is a major carbon dioxide producer and electricity usage is a consistent component throughout the DWL of the building.

When only considering the materials, the pre-use phase is the biggest contributor to the carbon footprint, as this is the phase where most of the manufacturing of materials is included.

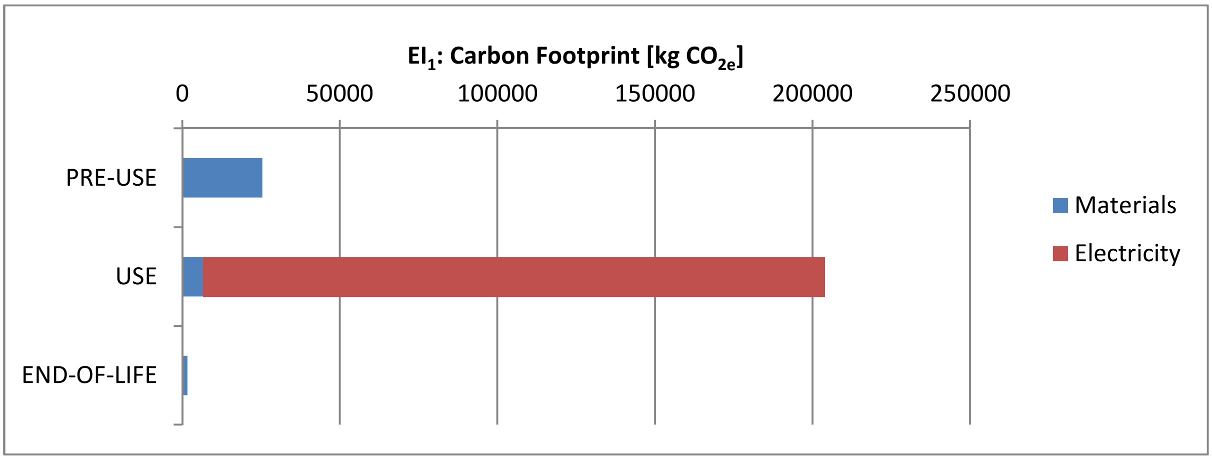


FIGURE 6-2: EI1 OF REFERENCE BUILDING, PER PHASE

Another option is to consider the contribution of the various individual components of the building throughout the entire life cycle.

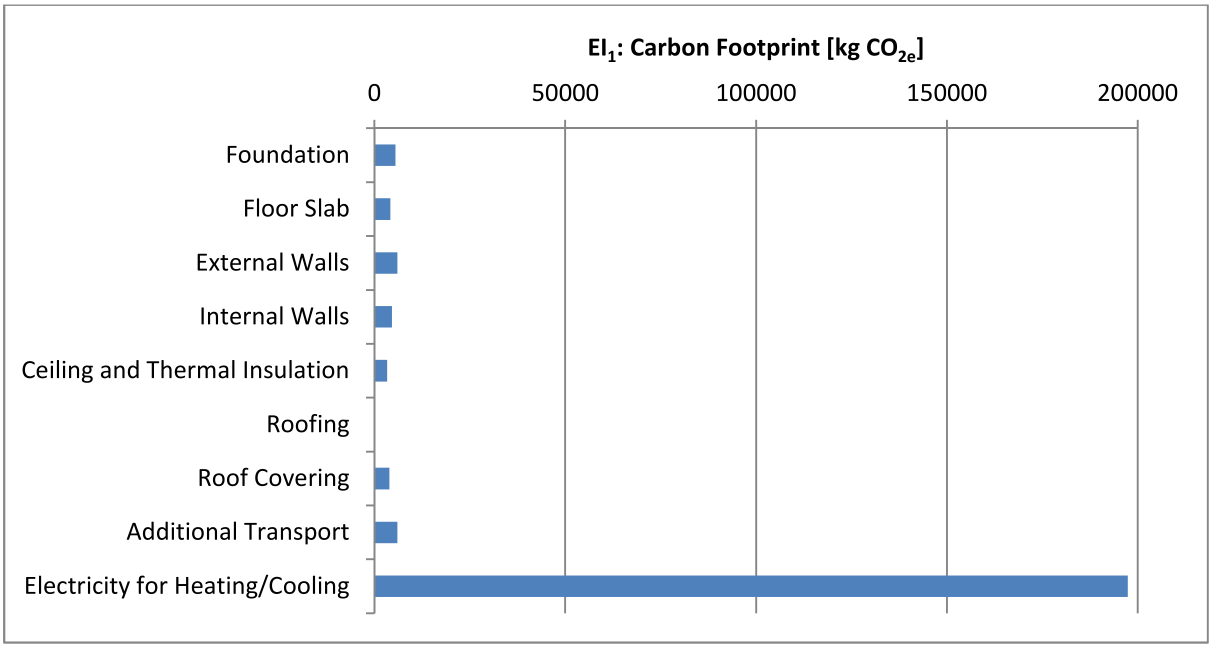


FIGURE 6-3: EI1 OF REFERENCE BUILDING, PER COMPONENT (ALL)

As the electricity contribution is so much larger, to scale (see Figure 6-3), it makes it difficult to evaluate the rest of the components. It was therefore decided to consider only the values of the materials sections, excluding the electricity from Figure 6-4.

This can be done in such a way that only the contribution to the entire life cycle be expressed, or by also showing each category's contribution to the life cycle in terms of each phase. This interpretation, as seen in Figure 6-4, offers the most useful representation of the component contributions to the life cycle of the building.

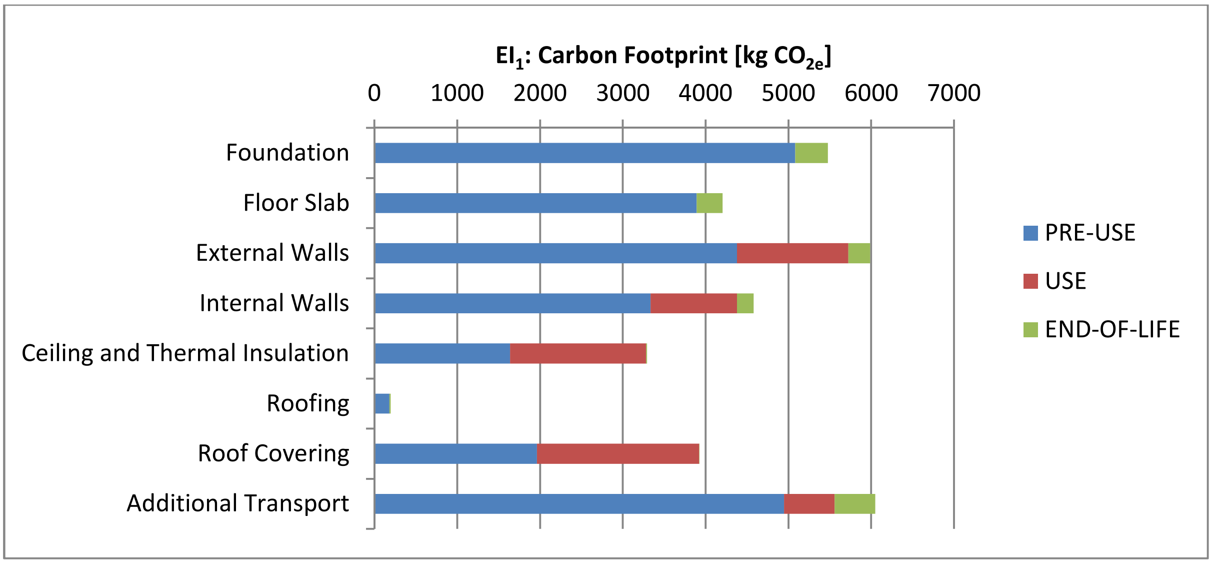


FIGURE 6-4: EI1 OF REFERENCE BUILDING, PER COMPONENT, PER PHASE (EXCL ELECTRICITY)

Both the foundation and floor slab offer fairly high contributions, considering they do not contribute to the maintenance period of the life cycle. In contrast, the roofing offers almost no contribution. This is due to the fact that the roofing consists only of wooden components, which do not require maintenance and are incinerated at the end of their life cycle.

The biggest contributors overall are those related to the external walls and the additional transport. Not much can be done to combat the contribution from additional transport, as this is fixed-dependent on the location of the construction site in relation to both the factories and the disposal sites. The contribution of the external walls, however, can change in relation to the type of materials that are used in the construction of the external walls.

6.2. Acidification Potential

Acidification potential measures the amount of the harmful gas, sulphur dioxide, and its equivalents which are released into the air. This air pollutant does not only have dangerous effects on the environment, but also on human health.

From Figure 6-5, it is clear that the components that make up the roof have the biggest combined impact where acidification is concerned. This is due to the type of materials used for the roof covering and insulation (both of which are maintenance products with repeated impacts during one building life cycle).

In this case, the most likely cause is the high thermal conductivity of the materials compared to the high R-value required for the roof structure. Considering materials with both a lower thermal conductivity and a lower acidification potential could resolve this problem, depending on the other environmental impacts of the new materials.

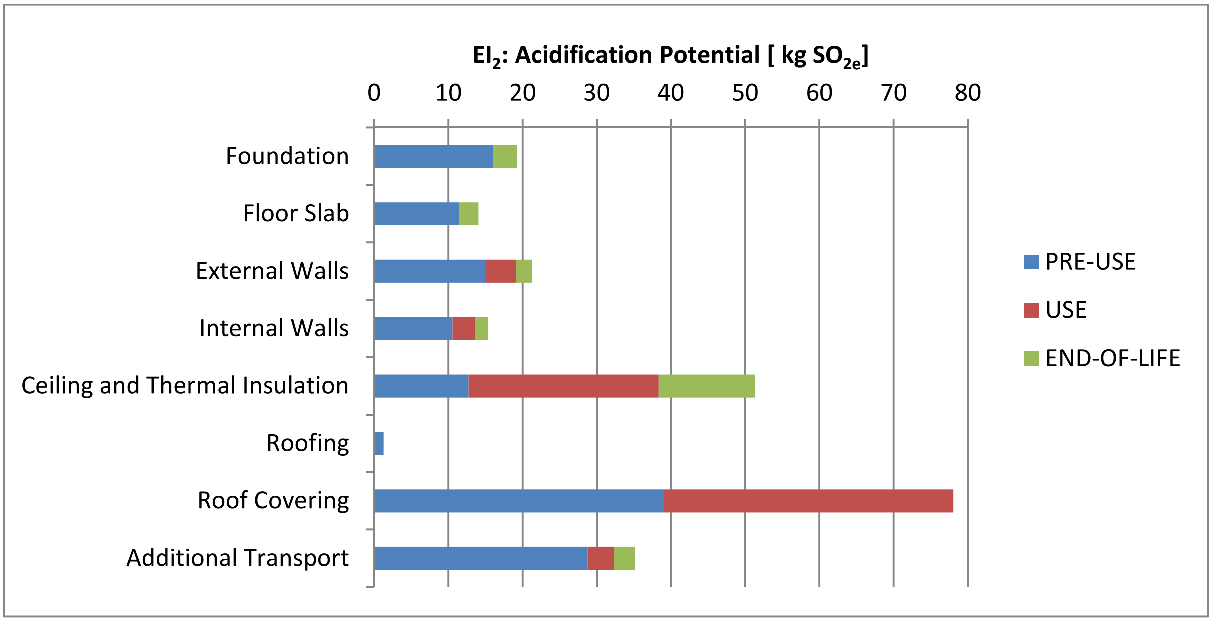


FIGURE 6-5: EI2 OF REFERENCE BUILDING, PER COMPONENT, PER PHASE (EXCL ELECTRICITY)

6.3. Eutrophication Potential

Eutrophication potential is a measure of the nutrient enrichment of soil and water. It can cause major long-term consequences for the natural environment. It was originally included as part of the end-of-life phase, as it has the potential to have key impacts during waste disposal at landfills. However, as can be seen in Figure 6-6, it has a rather small impact in the end-of-life phase when compared to the pre-use phase impact.

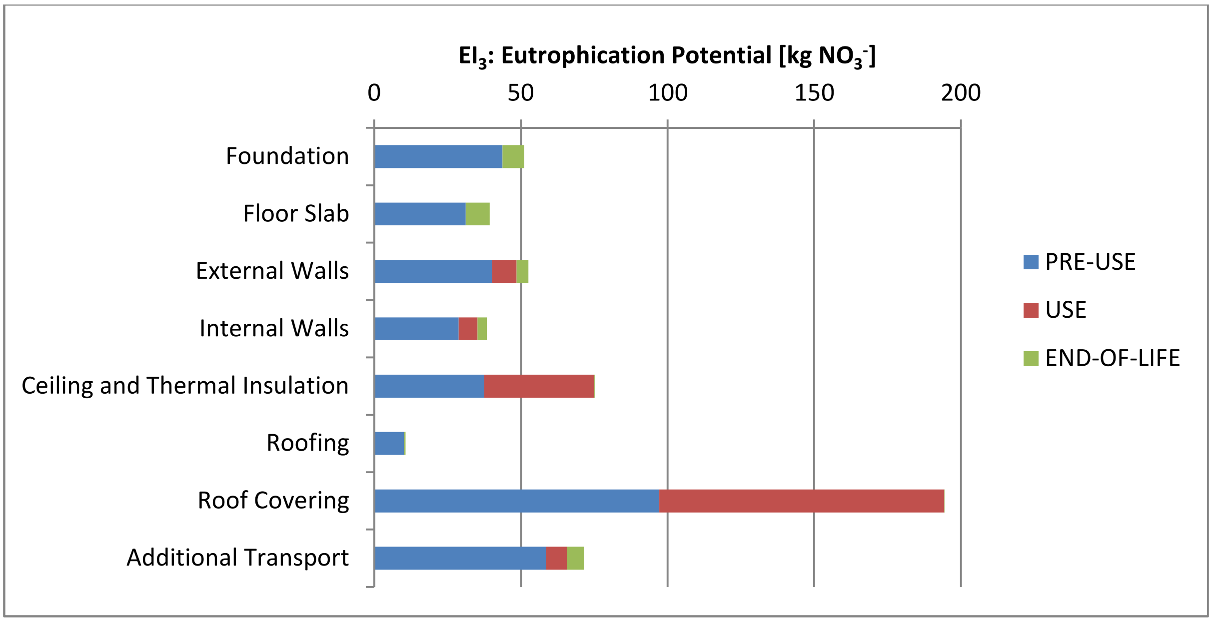


FIGURE 6-6: EI3 OF REFERENCE BUILDING, PER COMPONENT, PER PHASE (EXCL ELECTRICITY)

As with the acidification potential, the roof components of the reference building also have the highest combined impact when it comes to eutrophication potential. Once again the same reasoning can be applied: too much of a high-impact material was needed due to the material's high thermal conductivity and the high R-value required for the roofing structure. New materials should be considered to try to lower this EI.

6.4. Resource Depletion

Resource depletion, measured in MJ_{eq}, is a measure of the exergy needs related to a certain product. As opposed to energy, which simply measures “motion or the ability to produce motion”, exergy is a measure of “work (or ordered motion) or the ability to produce work” (Bösch *et al*., 2007:182).

By analysing the resource depletion, an estimate of the minimum work required to form all of the resources used in the building envelope can be determined. In this case it considers all renewable and non-renewable material resources (water resources, minerals and metals), as well as the only major non-renewable energy resources in South Africa (fossil).

The data in Figure 6-7 gives a breakdown of where the most resource depletion can be found. Again, additional transport has a fairly prominent impact overall, with the majority of the impact featuring in the pre-use phase. In the case of resource depletion, this is due to the transport’s significant use of fossil fuels.

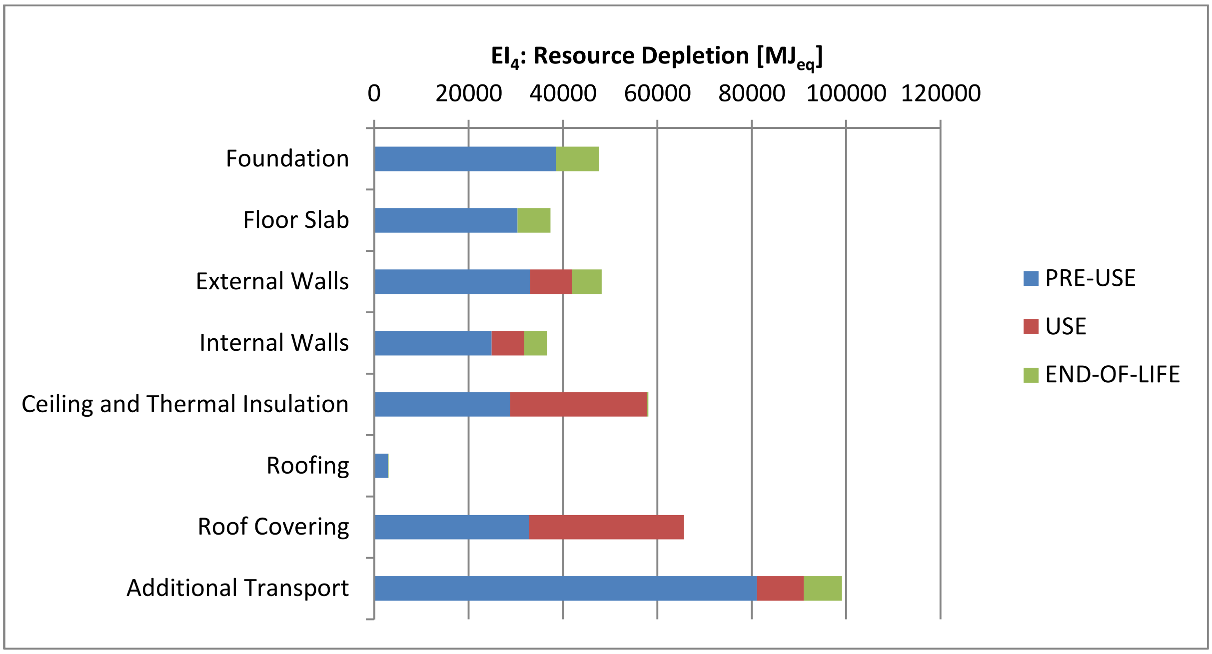


FIGURE 6-7: EI4 OF REFERENCE BUILDING, PER COMPONENT, PER PHASE (EXCL ELECTRICITY)

The additional transport is directly influenced by the weight of the building materials and the distance from the factory to the construction site. Possible solutions are to find building materials and components closer to the construction site or to use lightweight materials, if and where possible.

6.5. Waste Generation

Waste generation, by definition, plays a major role in the end-of-life phase. This is the only environmental factor where electricity use is a rather insignificant contributor, and it has therefore been included in all analysis graphs.

The most significant component contributors in this EI category (see Figure 6-8) are foundation, floor slab, external walls, and internal walls. These are all components where concrete is the main material, for this design. As the initial assumption for the reference design is that most products are moved to a landfill at the end-of-life, this is the material that has the biggest contribution to the landfill waste.

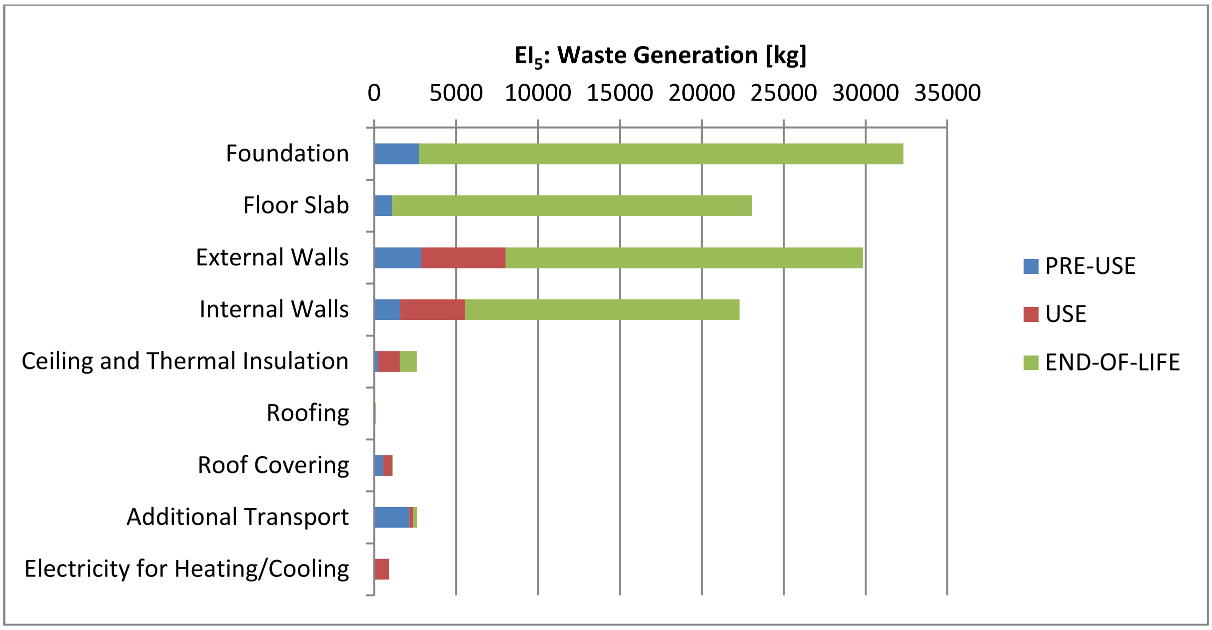


FIGURE 6-8: EI5 OF REFERENCE BUILDING, PER COMPONENT, PER PHASE

The most effective way to combat or improve waste generation is through reuse and recycling strategies.

Chapter 7: Environmental Life Cycle Assessment as an Optimisation Tool

The application used in this study aimed not only to assess the environmental impact of individual buildings, but also to show the LCA tool's capability as a comparative and optimisation tool. A demonstration of this capability was done by calculating the impact of different external walling designs on a building.

A reference building was designed to comply with the minimum SANS 10400-XA requirements. This reference building was then altered by changing only one variable: the external walls. Eight different alternative external walling systems were also analysed.

The main objective was to understand how the change in external wall designs can influence the environmental impact of the building as a whole, with a great expectation that a significant impact will be seen on the necessary energy usage for heating/cooling purposes.

To this extent, it is important to note that the operation component of the use phase, which represents only the energy usage, has a dominant effect in the first four EI categories, and an almost insignificant effect in category EI_5 (waste generation). Figure 7-1 has been included to visually illustrate this occurrence, but only illustrates the condition of the reference building.

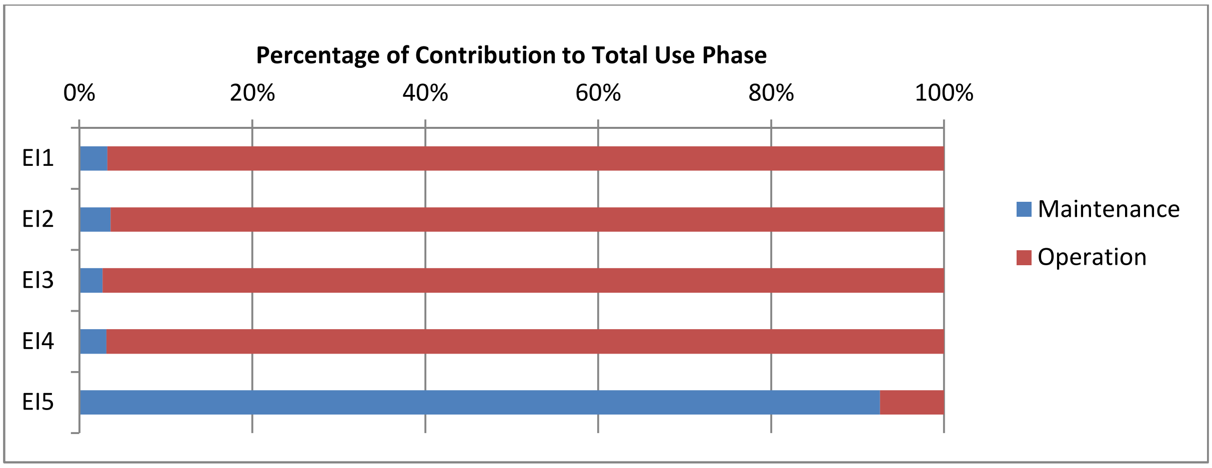


FIGURE 7-1: CONTRIBUTION TO TOTAL USE PHASE (REFERENCE BUILDING)

The same calculations were made for all the alternative designs as well, and it was found that in the first four EI categories, the operation component is always more than 91%. When it comes to EI_5, it was found that the maintenance component is always more than 92%.

The full environmental LCA for the reference design, as well as for the eight alternative external walling designs, can be found in Appendix D. Table 7-1 provides the abbreviations used for the external walling systems in the results.

TABLE 7-1: EXTERNAL WALLING SYSTEMS

Abbreviation	External Walling System
EW 01	Reference Design Building
EW 02	Single Leaf Brick Wall (140mm)
EW 03	Double Leaf Brick Cavity Wall
EW 04	Cast Concrete Wall
EW 05	Innovida Building System
EW 06	Affordable Comfort Homes
EW 07	MG Sip Building System
EW 08	Blast Building System
EW 09	Ikhaya Future House Building System

7.1. Individual EI Category Results

In order to simplify the understanding of the results, all alternative building designs were evaluated with reference to the impact results of the reference design building. An example of this calculation can be seen in Table 7-2.

TABLE 7-2: EXAMPLE OF REFERENCED IMPACT VALUES

EI_5 [kg]	Reference Building	EW05 Innovida Building System	Change in Value
Materials Impact	113944	83913	83913-113944 = -30031
Energy Impact	903	568	568-903 = - 335
Net Change in Impact			(-30031) + (-335) = -30366

This calculation has been done for each alternative external wall design, and for each of the five environmental impact categories. Figure 7-2 shows the results of EI_1 (carbon footprint) in kg CO_{2e} change.

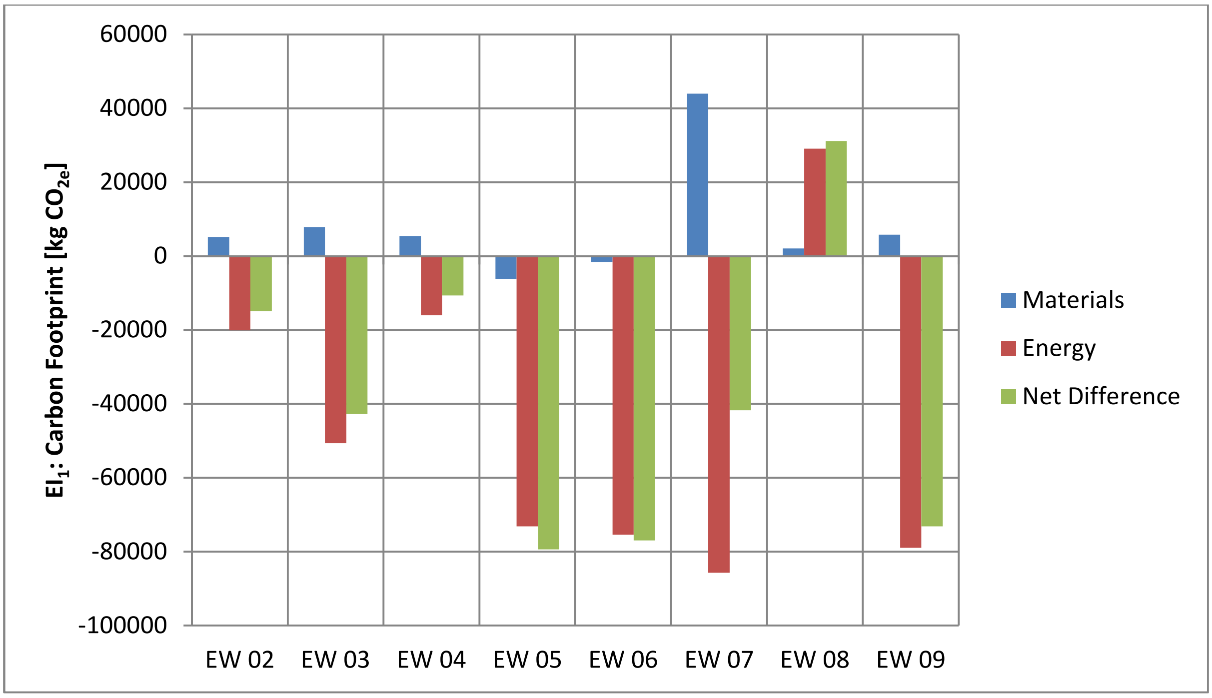


FIGURE 7-2: FULL LCA CARBON FOOTPRINT IMPACTS IN COMPARISON WITH THE REFERENCE BUILDING

The results from each separate EI category can be found in Appendix D10. As this study places emphasis on the impact of a change in external wall material on the use of energy, these individual EI results provide important insight. For example, when examining the results from the carbon footprint, it is interesting to note that both the Innovida Building System (EW 05) and the Affordable Comfort Homes (EW 06) show a decrease in the impact for both the materials and the energy, which causes the net decrease. Both of these walling systems contain an expanded polyurethane core, which has low impact factors, and therefore the decrease in materials impact can most likely be attributed to the presence of this material.

In contrast, the Blast Building System (EW 08) shows an increase in the EI_1 impact in both materials and energy, which leads to a net increase. It is important to note that the Blast Building System is also the only design to show a net increase in this EI category. This can easily be attributed to the fact that the Blast Building System consists of a significant amount of concrete, which increases the materials impact. It also does not reach the minimum required R-value, and therefore suffers an increase due to the energy impact as well.

The same holds true for EI categories two to four. Although most of the designs showed an increase due to the materials, the significant decrease due to energy led to an overall net decrease. All of the designs, with the exception of the Blast Building System, showed net decreases in categories EI_1 (carbon footprint), EI_2 (acidification potential), EI_3 (eutrophication potential), and EI_4 (resource depletion).

The exception to this trend can be seen in EI_5 (waste generation) (see Figure 7-3). The reason for this is that energy, as previously mentioned, is not a key contributor to this impact category. As a result, a decrease in energy usage has an almost insignificant impact in this category.

However, it is also interesting that there are still three designs that show a net decrease. They are Innovida Building System (EW 05), Affordable Comfort Homes (EW 06), and MG Sip Building System (EW 07). These net decreases are however attributed to the significant decreases due to the materials impact in this EI category, which in turn can be attributed to the type of materials used for the construction of these walls.

FIGURE 7-3: FULL LCA WASTE GENERATION IMPACTS IN COMPARISON WITH THE REFERENCE BUILDING

7.2. Combined EI Results

The next step was to consider the combination of all the EI results in order to get a clearer understanding of the overall impact of each building design. To this effect, an environmental impact index (EII) was proposed by Brewis (briefly mentioned here in Section 3.2.4), as well as by Brits.

This proposed EII, although practical, cannot yet give verifiable results. Firstly, the EII cannot include all five EI factors, as EI_4 was not derived using the same method's LCIA results. A second problem is the fact that the normalisation and weighting factors have not been verified for the South African environment.

An alternative method was devised to measure the combination of the impact by giving the reference building a basis percentage of 100 in each EI category, and measuring the net change in impact for each building as a percentage thereof. An example of this calculation can be seen in Table 7-3. The results of these calculations have been combined in Figure 7-4, with the results grouped together for each external walling system.

TABLE 7-3: EXAMPLE OF REFERENCED PERCENTAGE CALCULATION

	EI_5 [kg]	Percentage Impact [%]
Reference Building Impact	113944+903 = 114847	100
Net Change in EW 05 (Innovida Building System)	-30366	-30366/114847*100 = -26.44

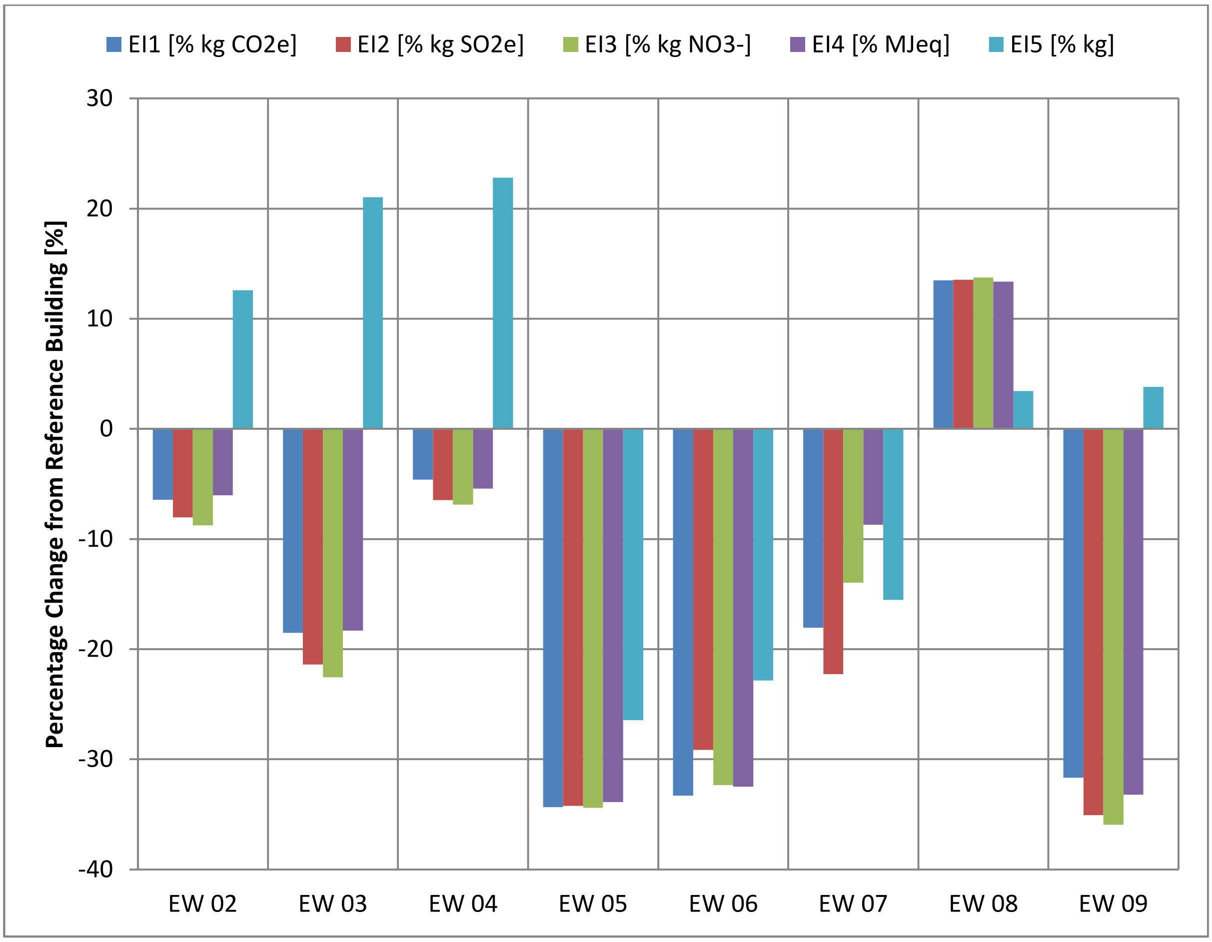


FIGURE 7-4: NET CHANGE IN ENVIRONMENTAL IMPACTS AS A PERCENTAGE OF THE REFERENCE BUILDING'S TOTALS (GROUPED BY EW)

This method does not provide definitive results, for example if these results were to be used to compare the Single Leaf Brick Wall (EW 02) and the Double Leaf Brick Cavity Wall (EW 03). EW 02 shows decreases in the first four EI categories, while showing an increase in waste generation (EI_5). EW 03 shows the same type of result, but to a much greater extent in all categories. The question then is which EI category is most important—if it is one of the first four categories, then the higher decrease in impact will be most valued, but if it is category EI_5, then the lower increase in impact will be most valued.

The dilemma here is that there is no conclusive answer as to which category is more important, and to what degree. This is where the use of a combined EII could prove useful, which would require steps such as normalisation and weighting.

However, environmental impact is not the sole measurement of sustainability. It is at this point where further sustainability factors could be considered and applied. If no definitive answer can be found from the graph, the top performing choices can then be analysed according to relevant economic and social factors in order to make the optimum choice. For example, if several designs perform similarly in terms of environmental impact, a choice can then be made based on the cost of construction.

There are also many additional answers to be gained from this kind of graph. Still considering the previous comparison, the information provided by the graph can provide the answers to improving individual external walling systems. For example, the increase in waste generation (EI_5) may be diminished by applying reuse or recycling strategies, and so improve one of the designs to such a degree that it is conclusively the better choice of the two options.

When considering the overall graph, taking all external walling systems into account, it is fairly easy to spot the best performers. Innovida Building System (EW 05), Affordable Comfort Homes (EW 06), and MG Sip Building System (EW 07) all show decreases in all five EI impact categories, with Innovida Building Systems showing the most improvement in all five EI categories. All three of these walling systems contain a polyurethane core, indicating that this might be an optimum building material for the core of the external walls of the structure.

Another way to interpret the results is by grouping the chart by EI category, if the aim is only to determine the external walling system with the most improvement in a specific EI category. This can be seen in Figure 7-5.

From this chart it is simple to deduce that Innovida Building System (EW 05) is the most improved external walling system in categories EI_1 (carbon footprint), EI_4 (resource depletion), and EI_5 (waste generation). Ikhaya Future House Building Systems (EW 09) is the most improved external walling system in categories EI_2 (acidification potential) and EI_3 (eutrophication potential). In contrast, the Blast Building System is consistently the worst performer in all categories, with the exception of category EI_5 (waste generation).

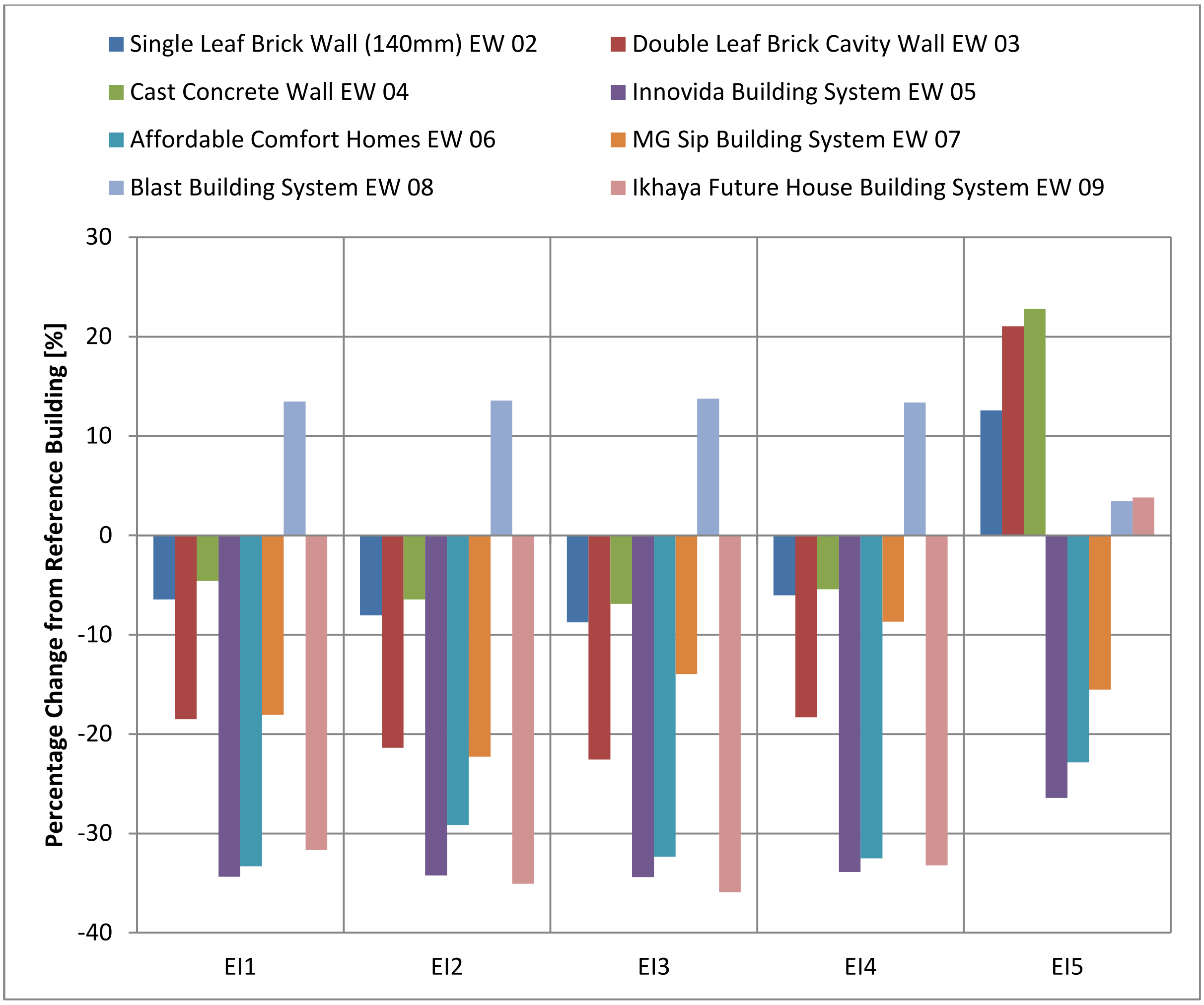


FIGURE 7-5: NET CHANGE IN ENVIRONMENTAL IMPACTS AS A PERCENTAGE OF THE REFERENCE BUILDING'S TOTALS (GROUPED BY EI)

7.3. R-value Results

As the only regulatory factor regarding external walls in the SANS 10400-XA code, the R-value should also be considered in these results. In order to do so, the results have been sorted and grouped in ascending order of the external walling system's R-value (see Figure 7-6). This is done in order to determine whether any specific trends form with regards to each EI category when only considering the R-value.

As previously mentioned, the minimum required value for external masonry walls, as required by the SANS 10400-XA, is only 0.35. The reference building was designed to meet this minimum requirement and has an R-value of 0.354.

With the exception of EI_5 (waste generation), the increase in R-value leads to a downward trend in all other EI categories, only turning upward again for the highest R-value (4.957). The main reason for the deviation in category EI_5 can be attributed to the lessened impact of the energy usage in this category. There are no significant positive reactions to the decrease in energy use, and therefore the trend is mostly controlled by the types of materials used, and not the proficiency of the materials' thermal properties.

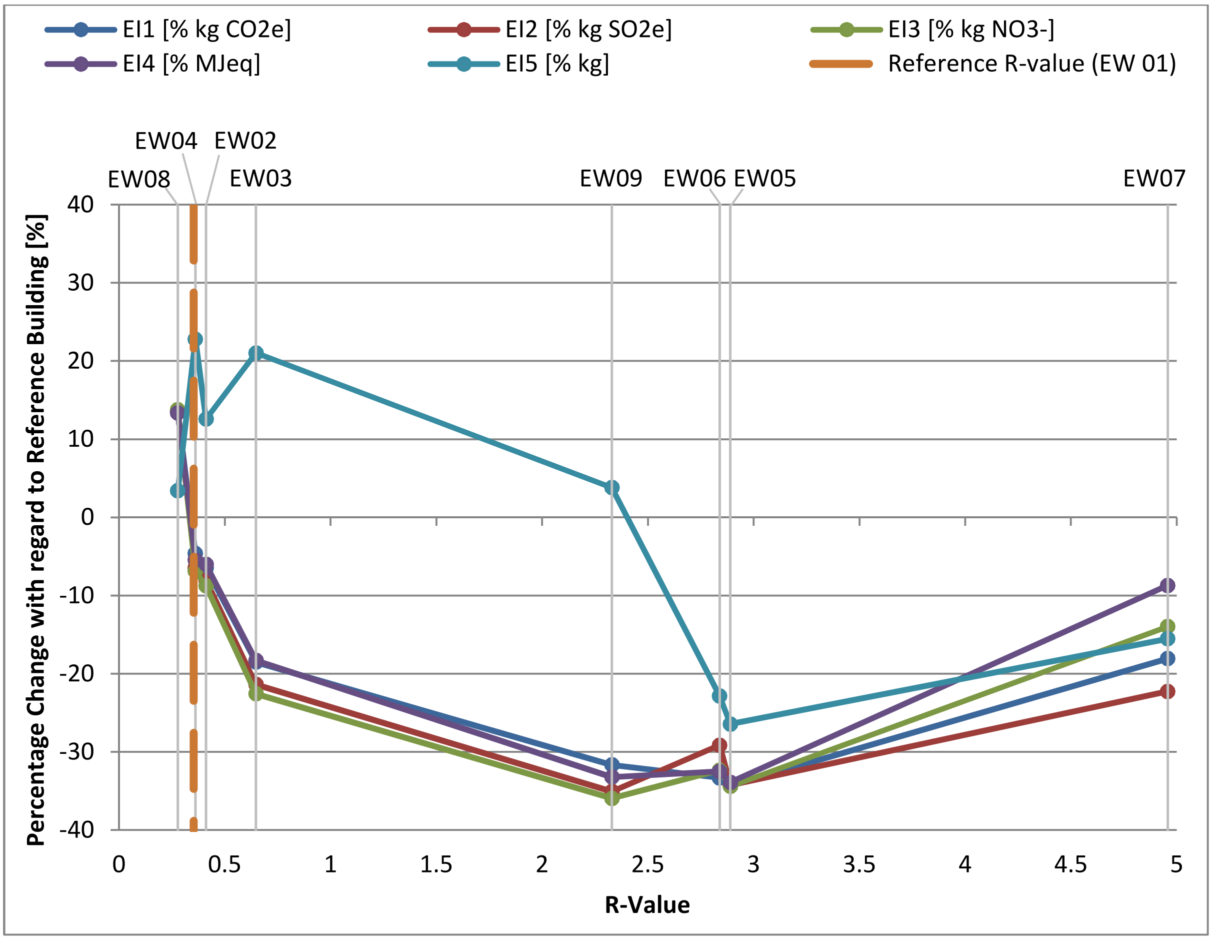


FIGURE 7-6: NET CHANGE IN ENVIRONMENTAL IMPACTS AS A PERCENTAGE OF THE REFERENCE BUILDING'S TOTALS (GROUPED BY EW, IN ORDER OF R-VALUE)

The graph, however, shows other significant trends when considering EI_1 to EI_4. Important data can be gathered by considering the slopes of the graph. When considering the four alternative EW systems with the lowest R-values (having an R-value range of only 0.37 from EW 08 to EW 03) there is an average net decrease of 32% to 36% in EI categories one to four. These decreases are significant when taking into account that the rest of the graph only experiences another 13% to 16% decrease. These steep slopes at the lower end of the graph indicate that small improvements in the lower-ranged R-values could have more significant impacts than changes in the higher-ranged R-values.

The graph continues to decline, though at a much flatter rate, before inclining again with the highest R-value (of EW 07). It is important to note, however, that even with the final incline, EW 07 still shows a decrease in impact when compared to the reference building impacts. The upward trend at the end of the graph indicates that the R-value could possibly reach a point where improving the thermal capacity requires such a major environmental impact that it can no longer be justified by the decrease in energy usage.

This, along with the basic shape of the graph, indicates that the possibility of an optimal R-range exists. However, the limited range of EW systems analysed in this study means that no conclusive inferences can be made from this graph alone. A more extensive study would need to be performed, with a broader range of R-values. Such a study would also need to be performed for each climatic region in order to achieve optimal, relevant results.

The limited results from this graph show how an increased R-value can have a positive effect on the environmental impact. More importantly, as the net change is so closely related and dependent on the decrease of the energy needed to heat and cool a building, it shows that the increased R-value can potentially improve the thermal conditions within the building. This is an important observation as the main application of this study is only done with consistently energy-heated/cooled homes in mind. However, just because a household cannot afford to use energy for space heating, does not mean that they do not need space heating.

Space heating can be a necessity when experiencing the weather extremes that South Africa has to offer. A 2012 study conducted in the Eastern Cape and Western Cape considered the impact of five different types of housing on temperature-related mortality, and found that an average formal-wealthy home can offer about 40% more protection from heat-related mortalities than an average informal home, and 45% more protection from cold-related mortalities (Scovronick & Armstrong, 2012).

It is therefore important that a more expansive study be done to test this correlation of R-value and thermal comfort, and how extensive this impact could be. An optimum R-value does not only hold the potential to improve the environmental impact of the homes of the wealthy, but also the potential to improve the quality of life for the poor.

Chapter 8: SENSITIVITY ANALYSES

8.1. TRANSPORT

Assumptions have been made in terms of the transport of materials, both between the factory and construction site, and the construction site and the landfill/sorting facility. It is important that these assumptions be checked, as the transport factor can make a large contribution to the first four environmental impact categories (especially to resource depletion, where it has in some cases made the largest contribution, with the exclusion of electricity generation).

A study on the additional transport between the factory and the construction site, which has been chosen as 100km, was performed by Brewis (2011:88).

A study on the additional transport between the construction site and the landfill or sorting facility, which has been chosen as 10km, was performed by Brits (2012:85).

As the complete environmental LCA makes use of both these assumed values, in several different capacities, it would be impractical to run a sensitivity analysis on both these values simultaneously, as there would be a need to make even more assumptions as to how the assumed transport distances vary relative to each other.

Therefore both additional transport distances were considered separately. The additional transport distance to the construction site was varied between 0km and 200km, at 50km intervals, while keeping the additional transport distance to disposal constant at 10km. The effect on the carbon footprint can be viewed in Figure 8-1.

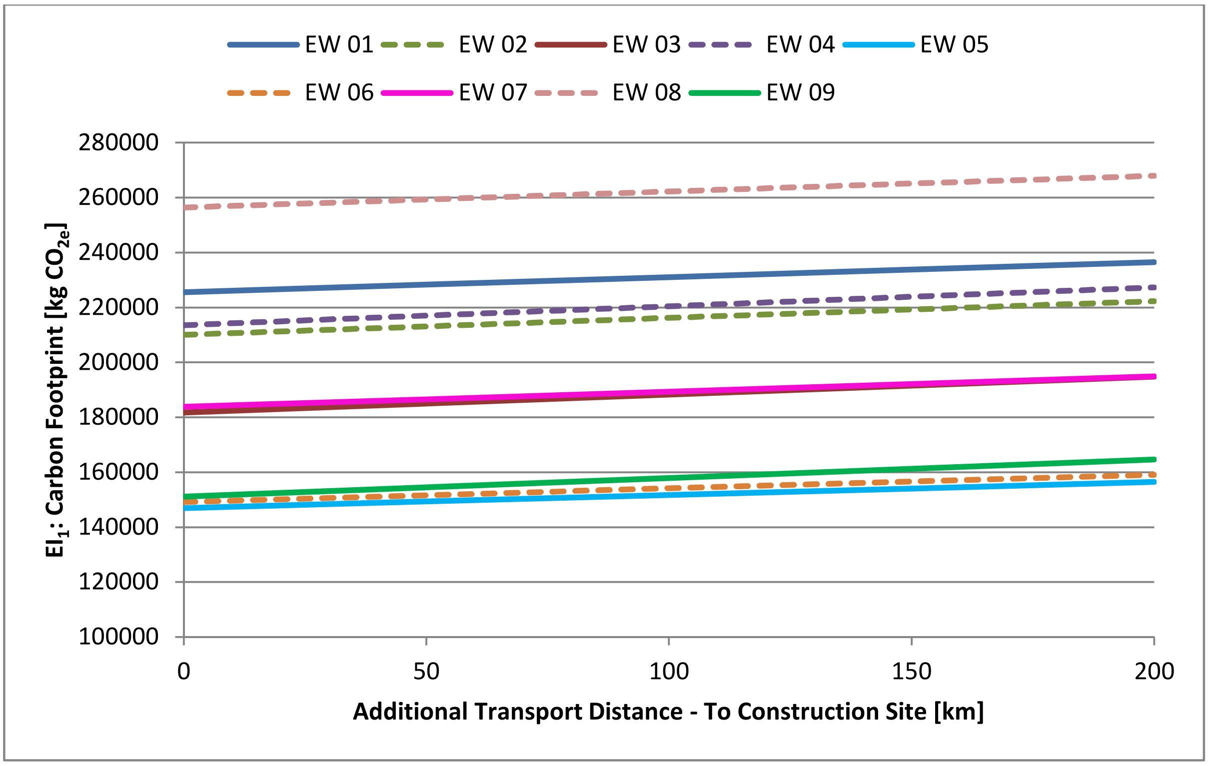


FIGURE 8-1: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE - EI1

The rate at which the EI increases does not differ much across the different building designs. The same result was found for the other four EI categories (which can be viewed in Appendix E1).

Next the additional transport distance to disposal was varied between 0km and 60km, at 10km intervals, while keeping the additional transport distance to the construction site constant at 100km. The effect on the carbon footprint can be viewed in Figure 8-2.

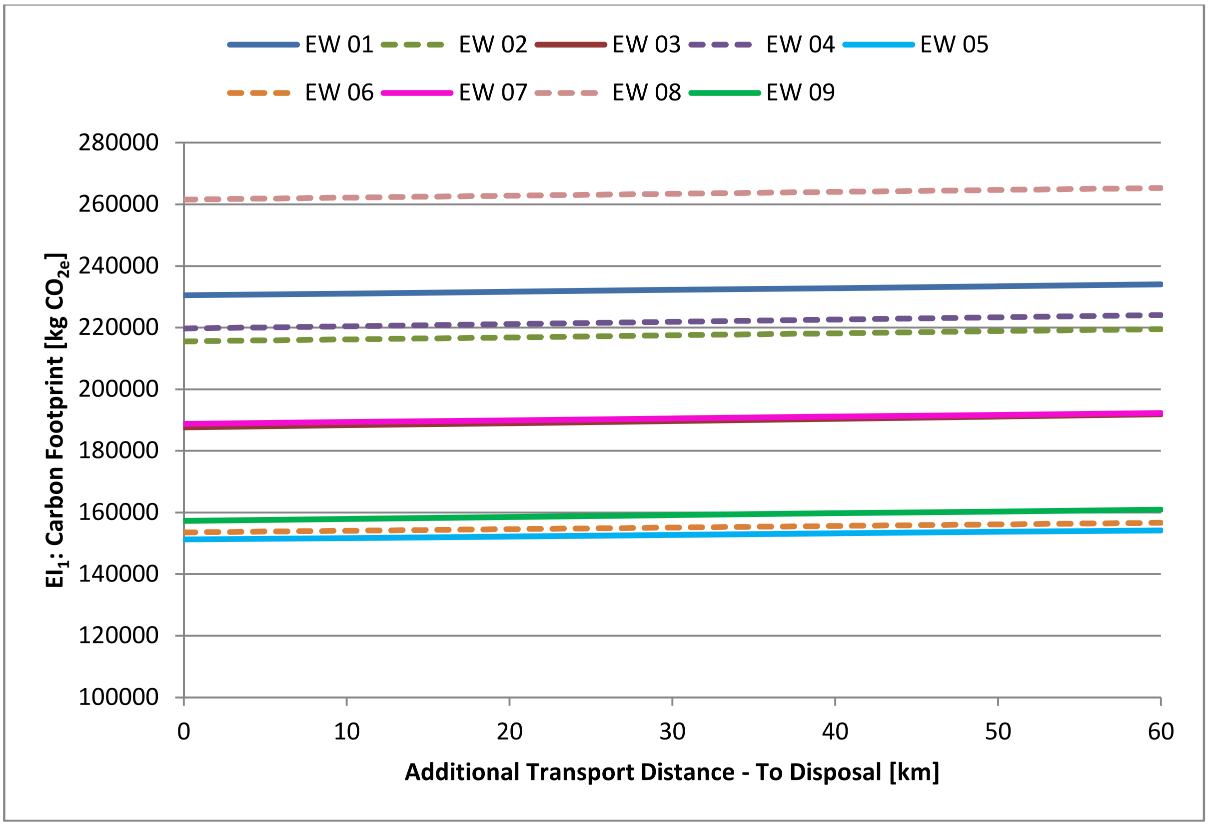


FIGURE 8-2: ADDITIONAL TRANSPORT TO DISPOSAL - EI1

As with the additional transport to the construction site, the rate at which the EI increases does not differ much across the different building designs, though the rate is even flatter. This can be explained by the fact that the assumed additional distance to disposal is significantly less than the assumed additional distance to the construction site, and therefore is varied over a much lower range. The same results were also found for the other four EI categories (which can be viewed in Appendix E2).

As the transport is a factor of both distance (in km) and the mass of the waste being transported (in metric tons), there will be some difference in impact between different building designs, as the designs do not have the same mass. The sensitivity analysis, however, does not reflect any major difference in the change in impact across the different designs, although the difference in the change in impact does increase as the additional distance increases.

The most accurate choice would be to not make any assumptions regarding the additional transport distance, but to rather use real values related to the transport of the materials for the building design.

8.2. Method of Waste Disposal

A detailed sensitivity analysis of the use of incineration as a waste disposal option was done by Brits (2012:90). The main calculations done in that study were also done using two different assumptions in terms of the methods of waste disposal during the end-of-life phase, as can be seen in Tables 5-1 and 5-2 of Brits (2012:57).

As can be expected, most building components showed a significant decrease in all environmental impact categories when sorting and recycling strategies were implemented, as opposed to landfilling. This same result is assumed to be true for this study as well. For detailed analyses and results, Brits (2012) should be consulted.

8.3. Design Working Life

As previously mentioned, the minimum DWL for a house is 30 years, with a maintenance cycle of 15 years. This means that maintenance will be performed once in a 30-year period.

However, if a house is well-constructed and well-maintained it can last much longer than 30 years. A simple study was done by varying the DWL of each design option from 30 to 75 years, in five-year intervals.

As the DWL increases, so do the operation needs, as well as the number of times that routine maintenance is required. It is therefore expected that the EI factors will steadily increase as the DWL grows larger.

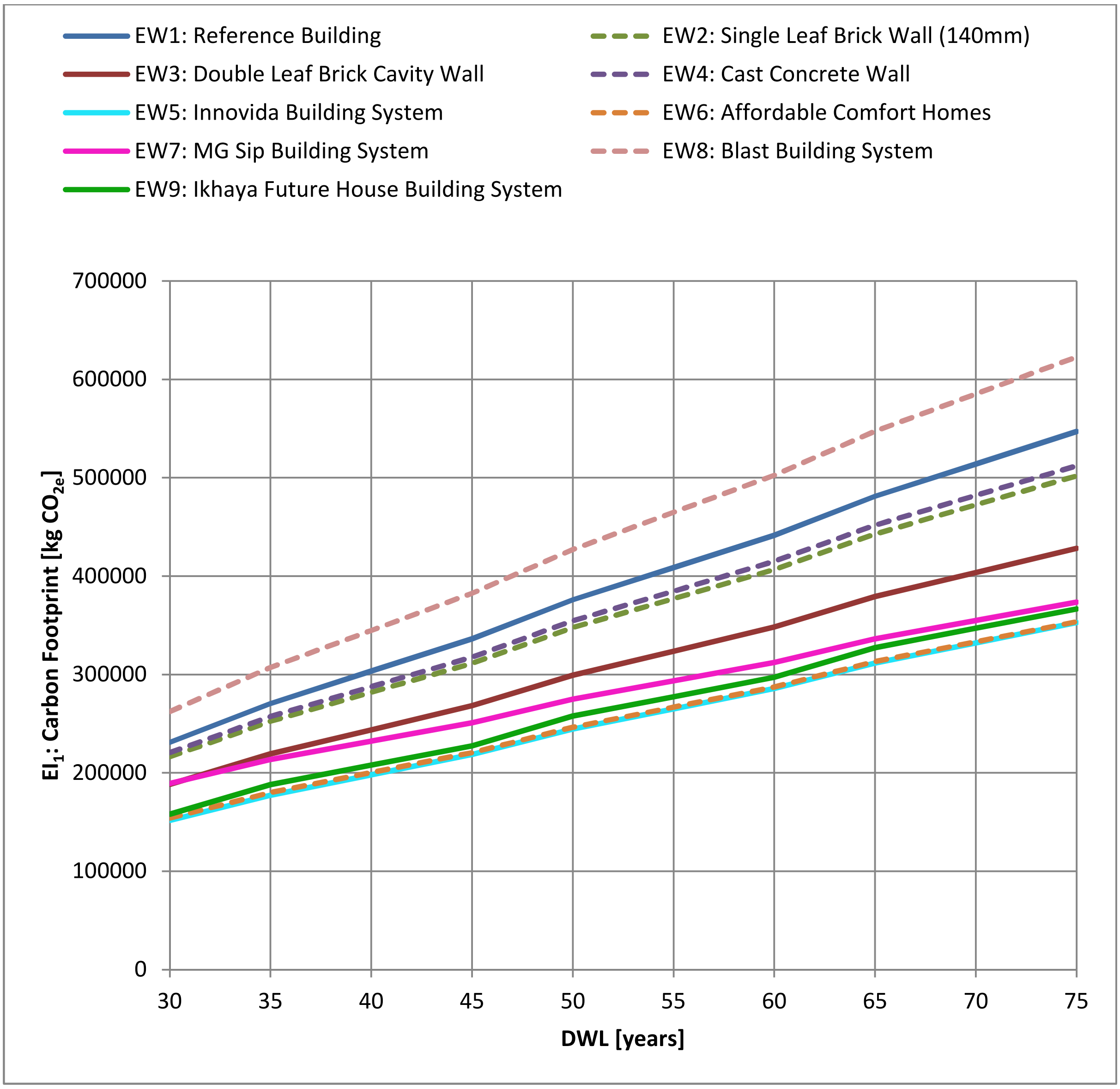


FIGURE 8-3: DWL SENSITIVITY ANALYSIS - EXAMPLE 1 (SAME AS FIGURE E-11)

This expected behaviour can be viewed for EI categories one to four, for each of the different building designs. For these four categories the operation (i.e. the electricity), which is a constant contributor each year of the

DWL, contributes about 97% to the total of the Use Phase (as was previously illustrated in Figure 7-1). Therefore the contribution from maintenance every 15 years does not cause much fluctuation in the slope.

There is, however, a minor difference, namely the rate at which the EI factor increases for each building design (see Figure 8-3). This can be explained by using the previous interpretation of results.

For building designs where the external walls offer better insulation, the need for electricity for space heating/cooling decreases. And as this is the main contributor to the slope, it means that the building designs with better insulation properties (like EW7: MG Sip Building System) will have a flatter slope than those with less efficient insulation properties.

There is a major difference when considering the fifth EI, Waste Generation. Electricity generation offers little contribution to this impact category (see again Figure 7-1). Therefore there seems to be almost no increase in this impact category with time, with the exception of the points in the DWL where maintenance is done.

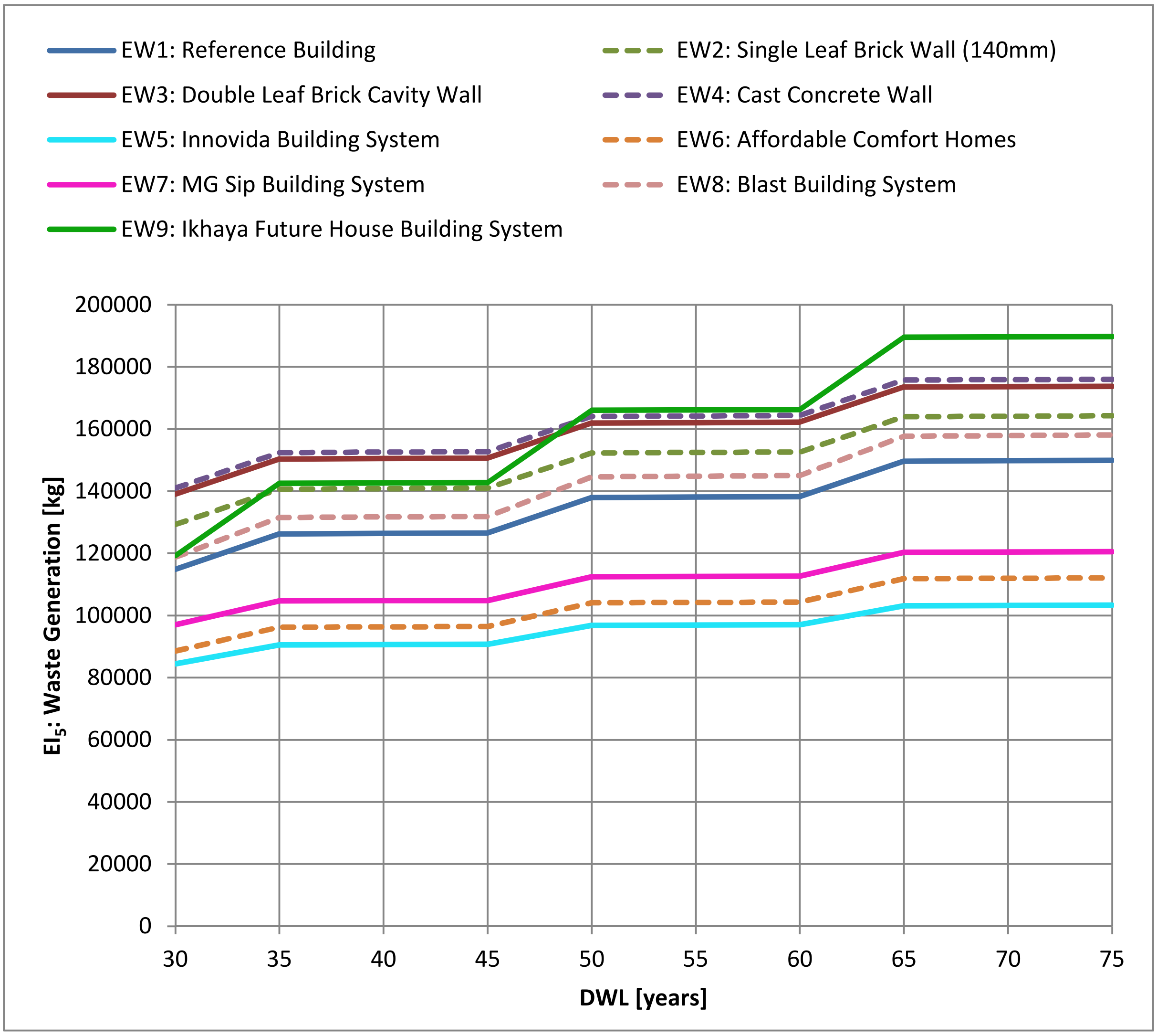


FIGURE 8-4: DWL SENSITIVITY ANALYSIS - EXAMPLE 2 (SAME AS FIGURE E-15)

There seem to be no abnormalities or unexplained behaviour/results to be found when considering the possible range of the DWL. The first four EI categories, however, show that the longer the DWL becomes, the wider the gap between worse-insulated and better-insulated building designs' EI categories become.

The result figures for all five EI categories can be found in Appendix E3.

A further sensitivity analysis was then performed to compare the impact of the building with an increased DWL with that of a building with the minimum DWL, which has to be rebuilt every 30 years. The time of construction and time of demolition were considered to be negligible in this calculation, and therefore the contribution of the electricity (operation component of the use phase) does not change.

The effect will be seen in the materials contribution, as the building which experiences rebuilds will suffer increased material contributions every 30 years. The graph in Figure 8-5 therefore has been constructed to illustrate the percentage increase/decrease in environmental impact from a single-build structure to a multiple-build structure. This has been done for each of the EI categories.

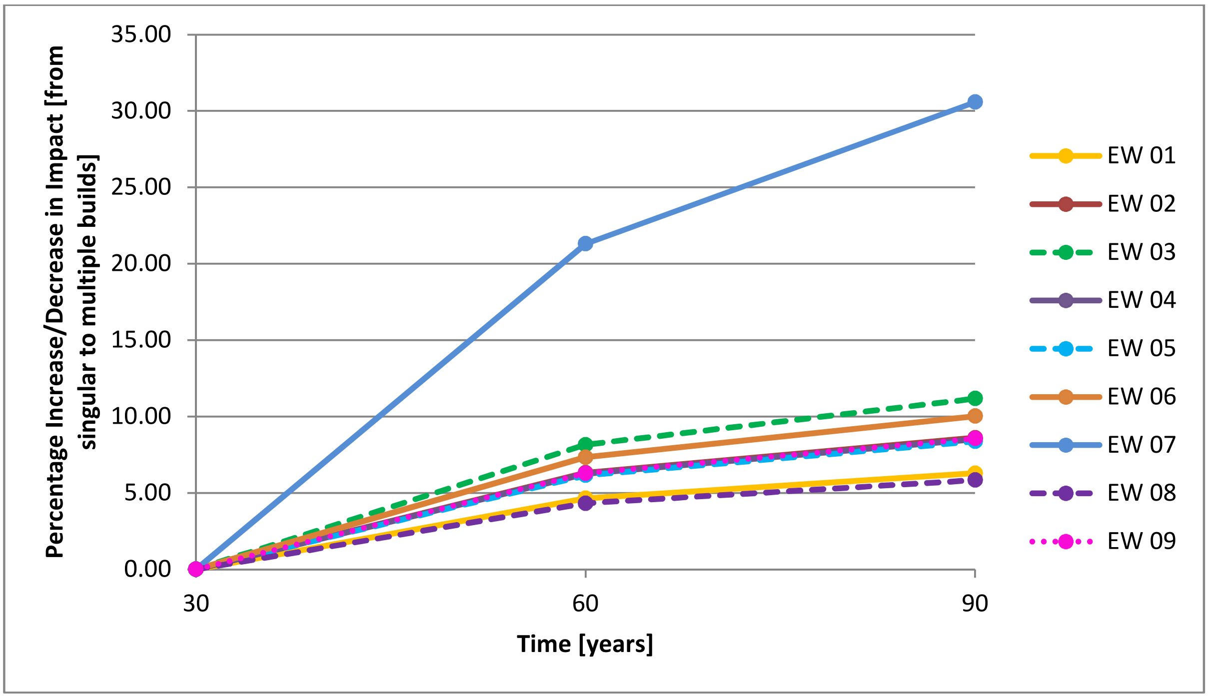


FIGURE 8-5: PERCENTAGE CHANGE IN CARBON FOOTPRINT (EI1) FROM SINGLE-BUILD TO MULTIPLE-BUILD STRUCTURES (FULL LCA)

Most of the structures experience a four to six percent increase in impact with the first rebuild, but only a further one to three percent increase with the second rebuild. This can again be attributed to the dominant impact of the operation component to the life cycle of the first four EI categories.

The outlier on this graph, EW 07, is the building with the greatest increase in impact due to materials contribution (this can be seen in Figure 7-2) and it is therefore expected that this building would experience the greatest consequences with regards to rebuilds.

EI categories two to four offer similar results (graphs can be found in Appendix E3), but the clear difference can be expected in EI_5, as this category is determined by the materials impact.

Figure 8-6 shows an average increase in impact of between 60% and 70% with the first rebuild, and a further 45% to 60% increase with the second rebuild. Similarly to the other graphs there is a decrease in the percentage change in impact with each additional rebuild cycle (30 year period).

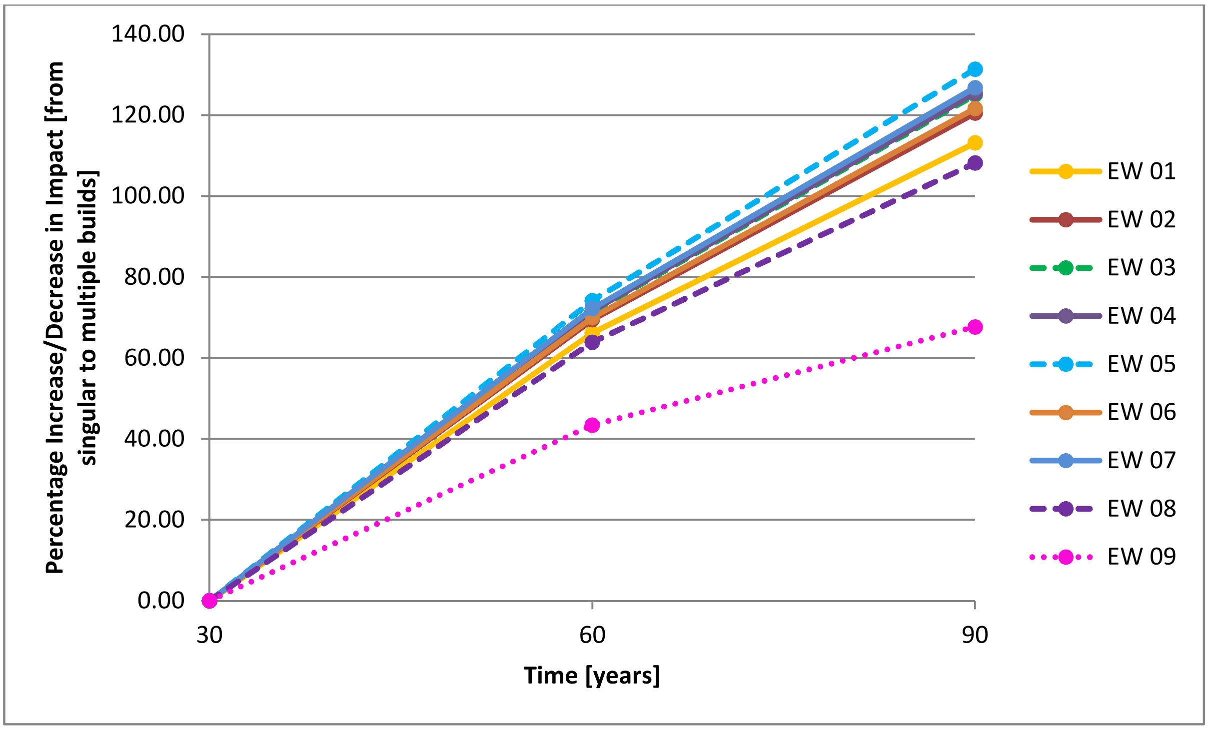


FIGURE 8-6: PERCENTAGE CHANGE IN WASTE GENERATION (EI5) FROM SINGLE-BUILD TO MULTIPLE-BUILD STRUCTURES (FULL LCA)

8.4. Amount of Space Heating/Cooling

The reference design makes the assumption that all rooms (with the exception of the bathrooms) make use of HVAC for heating and cooling purposes. HVAC is, however, an expensive commodity that few households can afford, and even fewer can afford to use throughout their homes.

While cooking, lighting, and heating water is seen as essential in most South African households (with very few to no households indicating they use no energy for these activities), space heating (in any capacity) is seen as a luxury that over a quarter of South African households simply cannot afford.

TABLE 8-1: HOUSEHOLDS INDICATING 'NONE' AS MAIN SOURCE OF ENERGY [SOUTH AFRICA, 2012]

Energy Use Category	Households that indicated 'none' as main source of energy
Cooking	0.2 %
Lighting	0.0 %
Heating water	1.2 %
Space heating	27.7 %

A second scenario has been considered where only the bedrooms and living room are assumed to have HVAC. In Figure 8-7, these are the three larger north-facing rooms and the south-facing room on the western side.

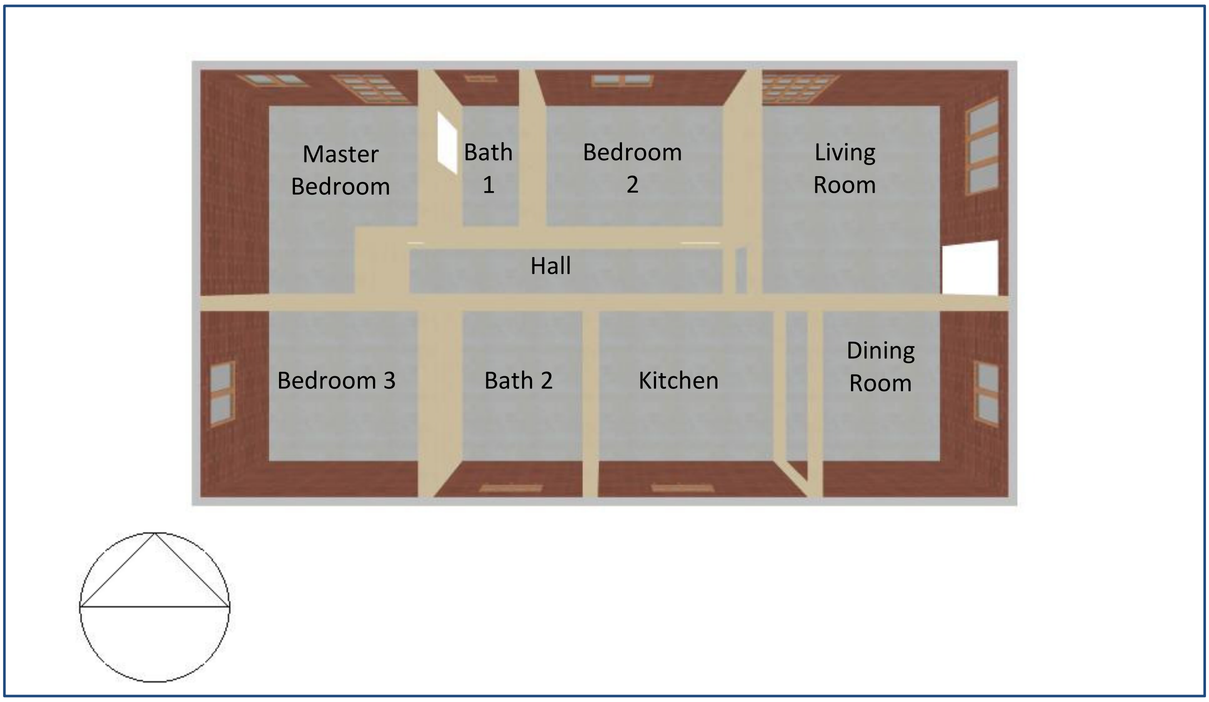


FIGURE 8-7: DESIGNBUILDER REFERENCE BUILDING (LAYOUT)

As can be expected, this of course gives a lower result for electricity usage, as less space needs to be cooled. When considering these values in kWh, there are major differences in decrease across the different building designs.

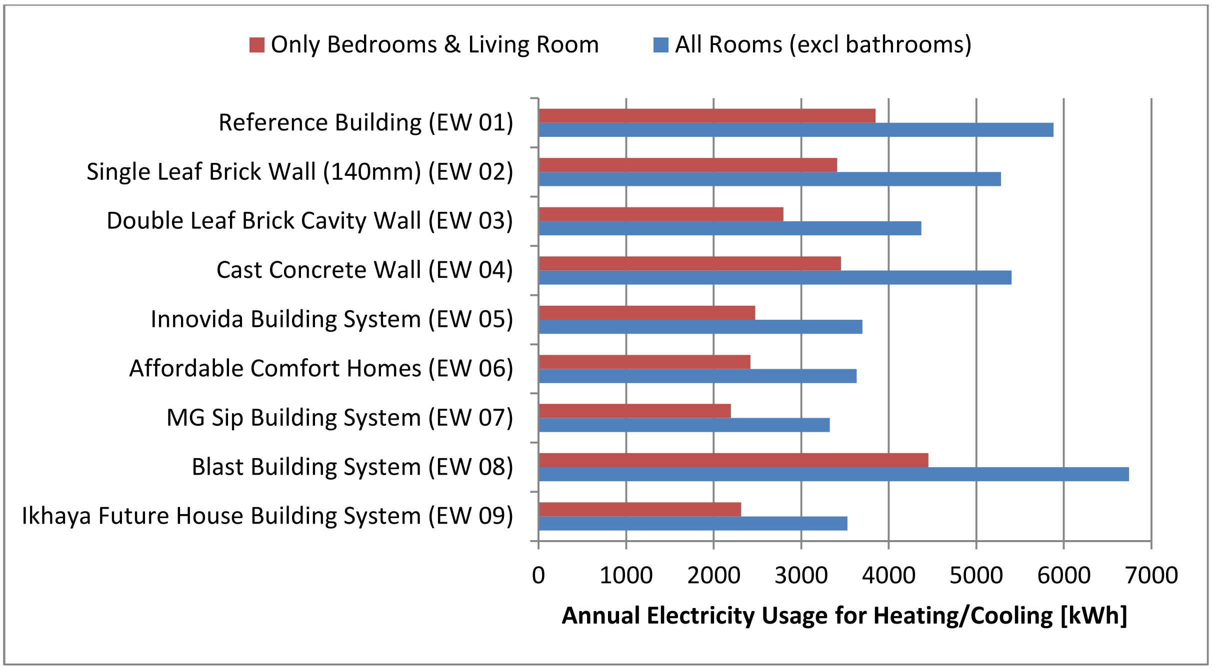


FIGURE 8-8: EFFECT OF AMOUNT OF SPACE TO BE HEATED/COOLED

In order to make the results comparable, the electricity usage found when using the original design assumption (for each individual case) has been designated as 100%. The lowered values for electricity usage, as derived from the second analysis, have now been expressed as a percentage of the original electricity usage. These results, as illustrated in Figure 8-9, show an almost consistent decrease in electricity usage of 35%, across all different designs. This shows that the energy usage decreases in relation to the decrease in the amount of space to be heated/cooled, irrespective of the type of external walling system.

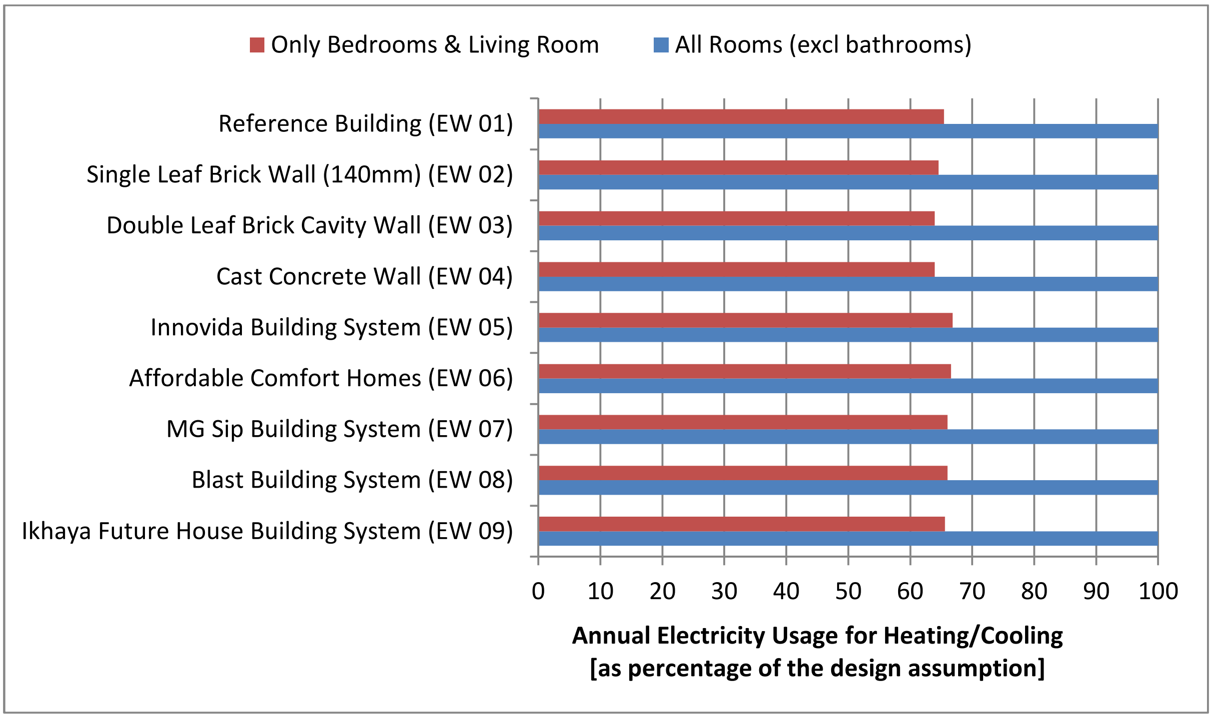


FIGURE 8-9: EFFECT OF AMOUNT OF SPACE TO BE HEATED/COOLED [EXPRESSED AS PERCENTAGES]

This means that even though the electricity usage might not change by the same amount between designs due to a change in the volume of space that needs to be heated or cooled, it will most likely change by the same percentage.

8.5. Site Orientation

Site orientation is a fairly simple way of complying with energy-saving requirements. Although it may be difficult in terms of the site layout or location of the building, it is generally not a design specification that requires difficult calculations. However, it can lead to large energy savings.

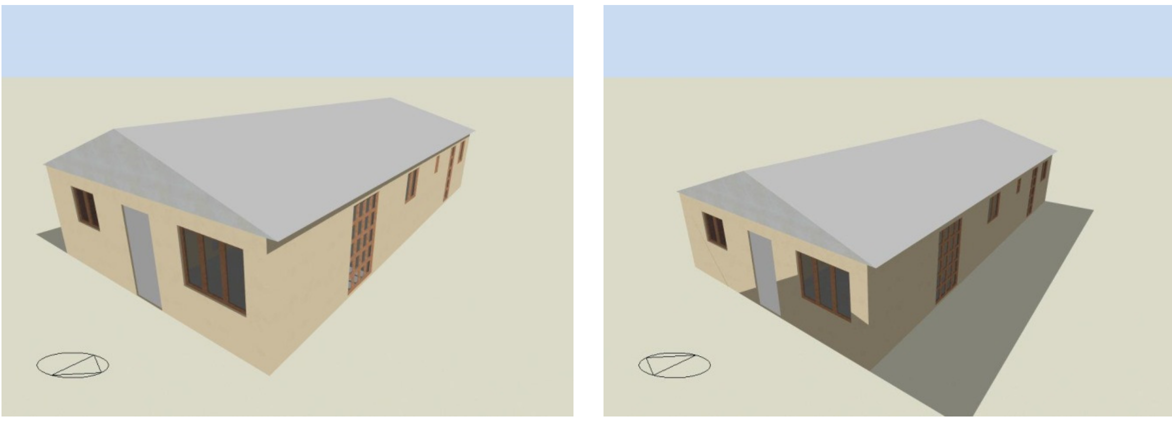


FIGURE 8-10: 0 DEGREE VS 180 DEGREE ORIENTATION VISUALISATION

The reference design building (as pictured in Figure 8-10) has been analysed using four different orientations, namely 0° (the optimum design assumption), 90°, 180°, and 270°.

The 0° orientation, which was the reference design orientation, is prescribed by Part XA (SANS, 2011c:9) and chosen in such a way that the most-lived-in rooms are north-facing.

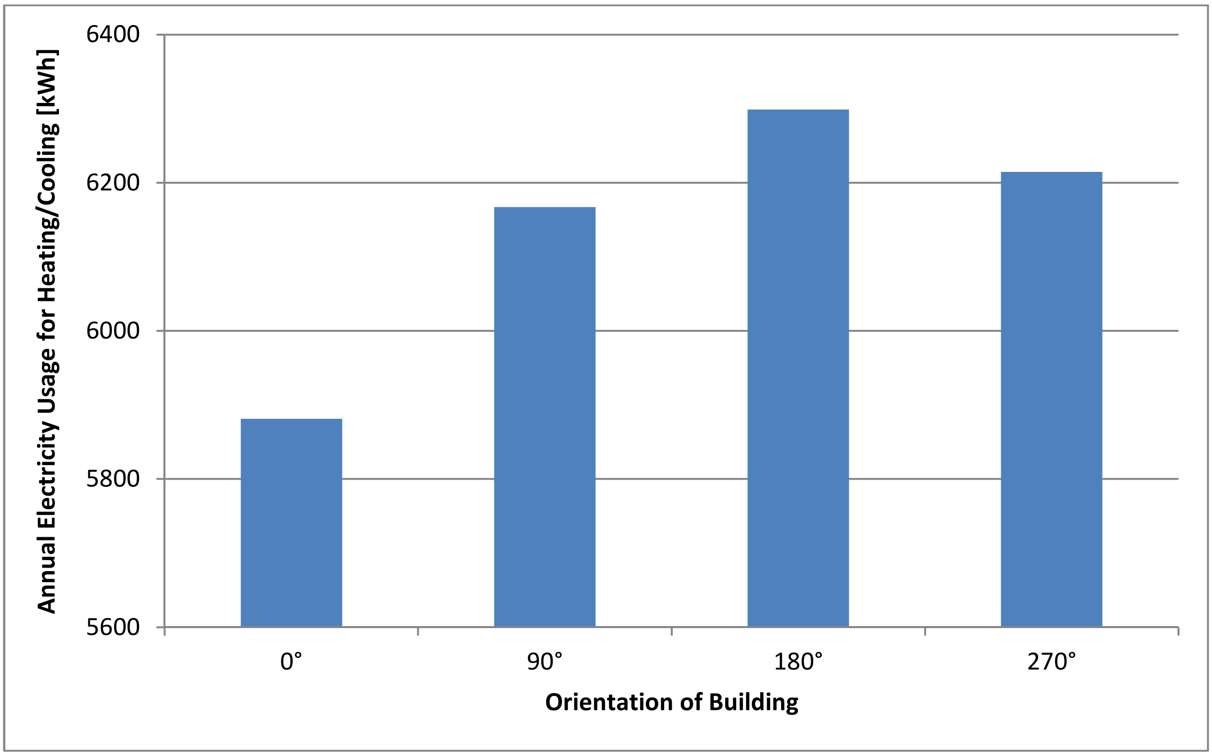


FIGURE 8-11: BUILDING ORIENTATION AND ELECTRICITY USAGE

There is an increase in electricity usage for all other building orientations (Figure 8-11), verifying the 0° orientation as the optimum building orientation. The 180° orientation shows an increase in electricity usage of just over 7%. This value may not seem that impressive, but when considering the electricity usage of the entire life cycle of a building, this value becomes a rather prominent figure.

8.6. Location

Location is an important factor in the heating and cooling designs, as these designs are governed by the climatic environment, which can differ dramatically depending on the region. To view the effect of location, the reference design building was evaluated for each of South Africa's six climatic regions, by using the representative city's climatic data in DesignBuilder.

Cape Town was the city that was used in the original design assumptions, and it has been highlighted in Figure 8-12 as a reference point. The chart shows major impacts on the electricity usage due to the location and design climate data that was used.

To make the results clearer, they have been expressed as a percentage of either an increase or decrease in electricity usage, with reference to the electricity usage in Cape Town (see Figure 8-13). This figure shows that this design, if located in Johannesburg, would increase electricity usage by almost 50% compared to if it were located in Cape Town. Similarly, the same the design, if located in Durban, would only use about half the electricity required in the Cape Town setting.

Location is therefore a factor that must be carefully selected. It is also clear that designs cannot be compared if different location data is used. If building designs are to be compared for design optimisation, the exact same location and climatic data needs to be considered.

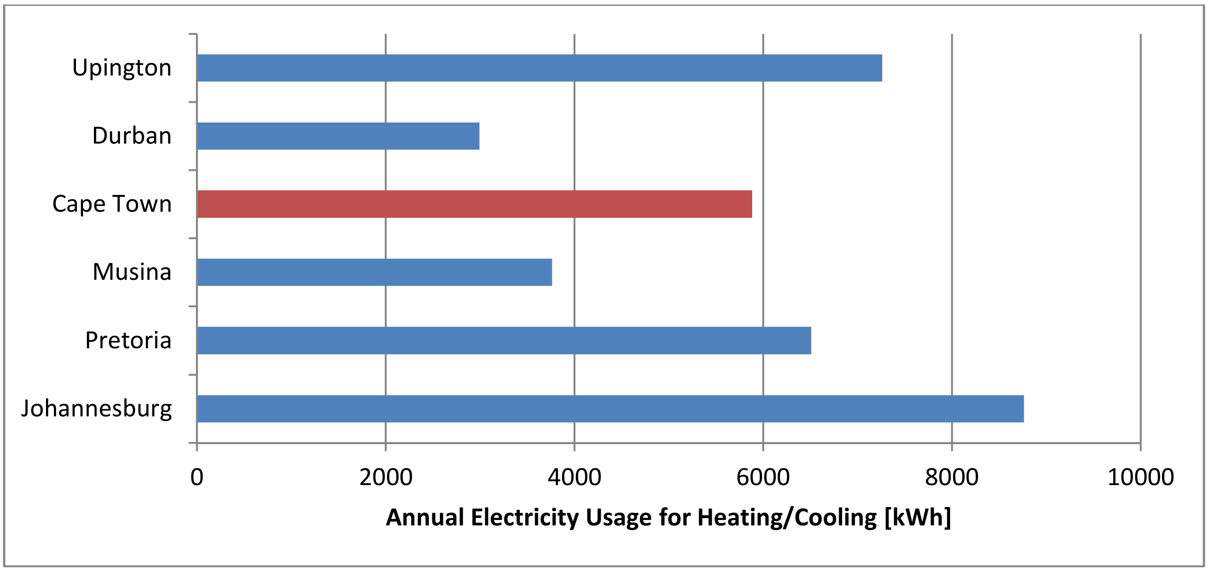


FIGURE 8-12: LOCATION AND ELECTRICITY USAGE FOR HEATING/COOLING OF REFERENCE DESIGN

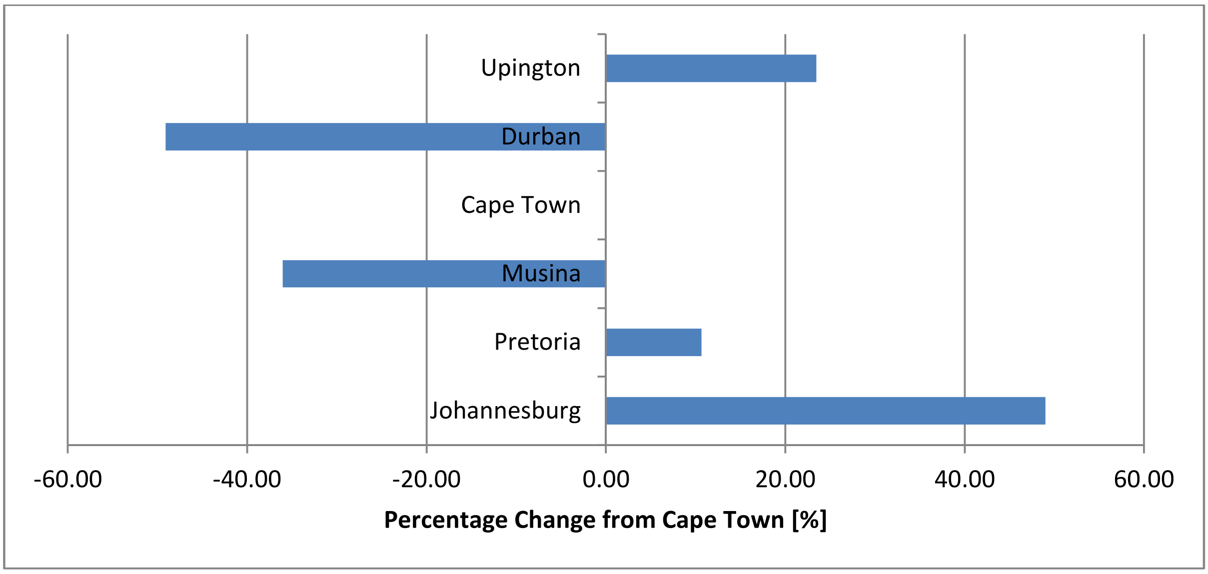


FIGURE 8-13: PERCENTAGE CHANGE IN ELECTRICITY USAGE (WITH REFERENCE TO CAPE TOWN)

8.7. Temperature Range

The required temperature range as prescribed by the SANS (2011c:8) is an unusual way of regulating the thermal environment of a building. This range (19°C to 25°C) is valid for all of South Africa, but as we have just seen in Section 8.6, the climatic regions of South Africa vary significantly. It was therefore decided to test the temperature range in four ways:

1. By lowering the range: 15°C to 21°C
2. By raising the range: 23°C to 29°C
3. By narrowing the range: 21°C to 23°C
4. By widening the range: 16°C to 28°C

The effect of this change in temperature range must be considered for both comfort and electricity usage. Comfort temperature was briefly discussed in Chapter 4, in relation to ANSI/ASHRAE Standard 55. One of the methods of measuring the thermal comfort of people is by calculating the Fanger PMV (predicted mean vote) value. This is an index method based on responses of comfort perceptions by people and ranges as follows:

TABLE 8-2: FANGER PMV INDEX

Fanger PMV	Description
+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

DesignBuilder automatically calculates the Fanger PMV value along with every temperature and energy calculation, at the same intervals. This can now be used to consider the comfort level of each temperature range (see Figure 8-14).

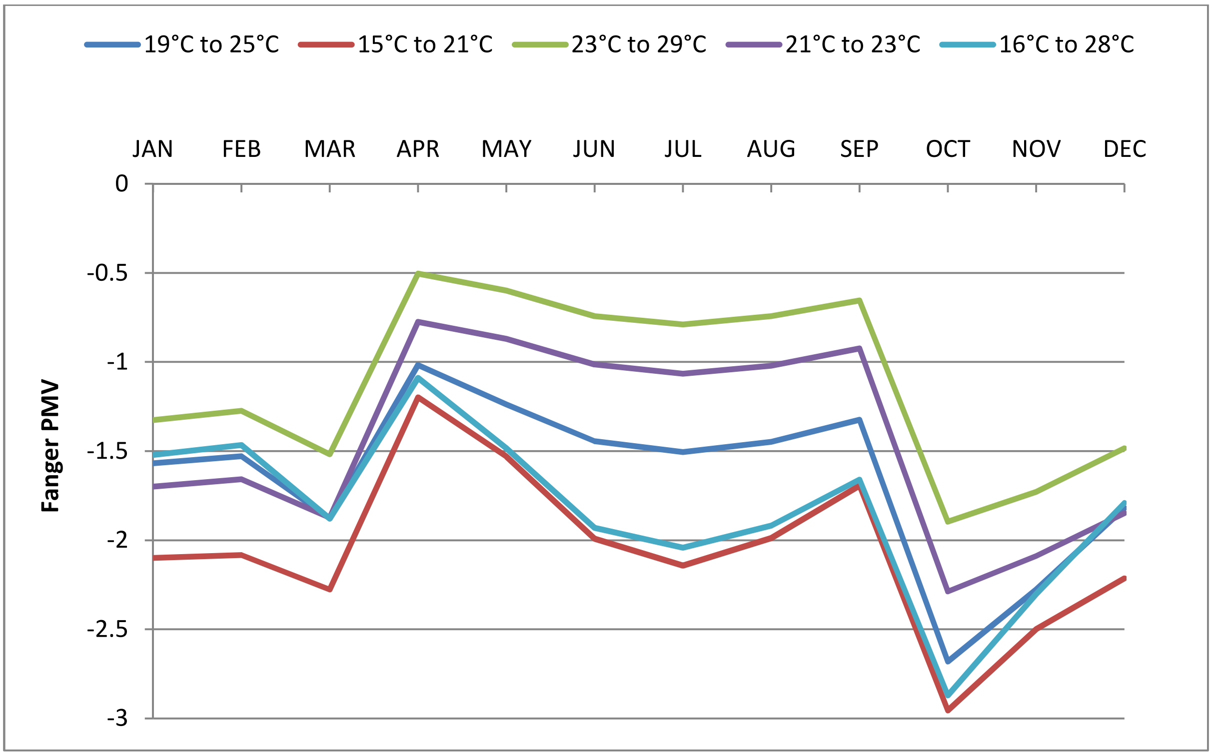


FIGURE 8-14: FANGER PMV FOR DIFFERENT TEMPERATURE RANGES

While none of the temperature ranges give a PMV close to neutral, some ranges clearly perform better than others. The range between 23°C and 29°C performs the best in terms of comfort, with an annual average of -1.1. Now it is necessary to also consider the change in electricity usage related to the temperature ranges.

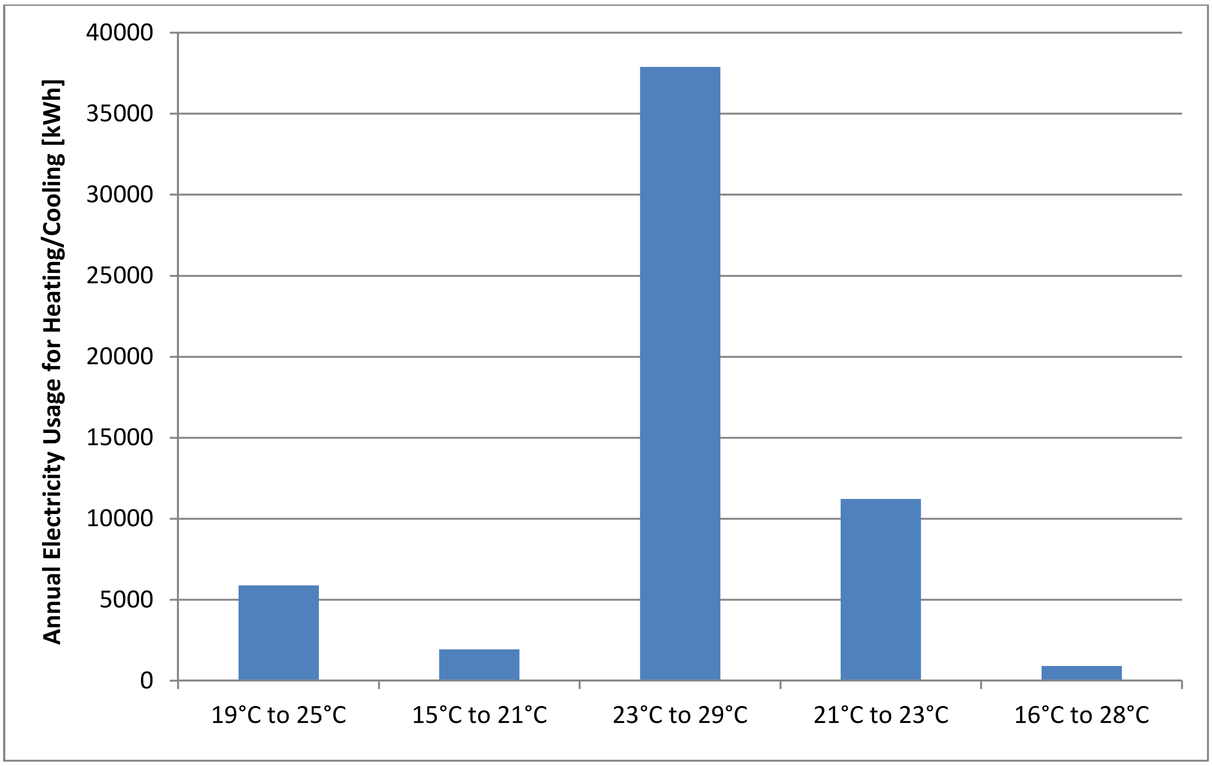


FIGURE 8-15: TEMPERATURE RANGE AND ELECTRICITY USAGE

It is clear that maintaining a higher thermal comfort level within the building requires much more energy usage, but this is to be expected.

The most important part to note is that the South African temperature range recommended in Part XA is clearly not the optimal range for thermal comfort in a house located in Cape Town. This shows that different temperature ranges should be allocated to different climatic regions, in order to increase the thermal comfort in buildings.

8.8. Operation Schedule

The reference building is designed for HVAC to be used 98% of the time of occupation, while the occupation in turn is also assumed to be 24/7.

This does not accurately reflect the schedule of a household. Therefore an alternate schedule was analysed to see the effect this would have on energy usage. The proposed alternative schedule can be viewed in Table 8-3.

TABLE 8-3: PROPOSED ALTERNATIVE SCHEDULE

	HVAC ON	HVAC OFF
Weekdays	16:00 to 08:00	08:00 to 16:00
Weekends	24 hours	None

This alternative schedule was applied to each of the building designs and the results can be viewed in Figure 8-16.

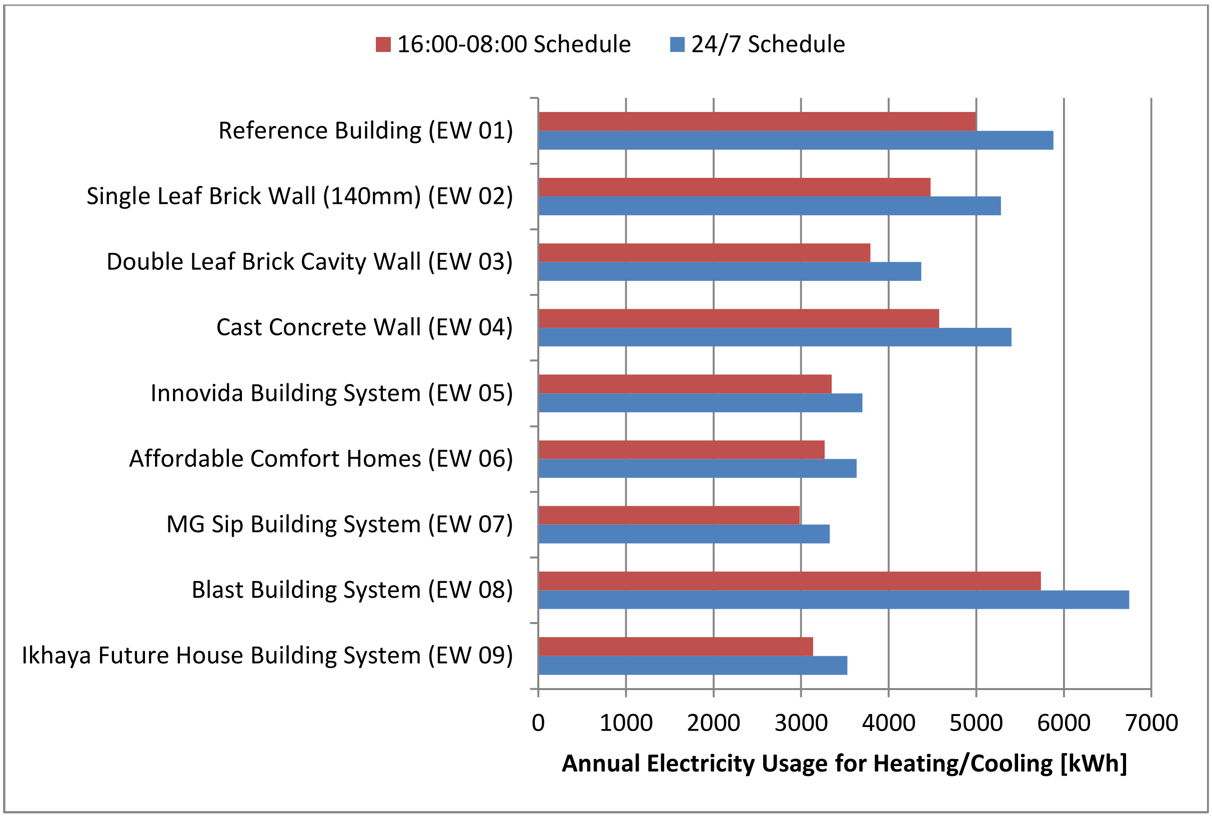


FIGURE 8-16: SCHEDULE (FOR OCCUPATION AND HVAC OPERATION) AND ELECTRICITY USAGE

While there is some reduction in electricity usage for each building design, it seems much smaller than expected (considering the HVAC usage has been turned off for one third of each weekday). This makes sense, however, when also considering the fact that the ratio of electricity for heating to electricity for cooling is extremely high. Therefore it is the cooler temperatures that govern the electricity usage, and these are most prevalent during the night (which is always included in this schedule).

As for the effect between different building designs, this follows much of the same pattern as Section 8.4. Although the amount by which the electricity usage is reduced with a shorter schedule will differ greatly across the different building designs, it tends to reduce by a similar percentage.

The percentage of reduction across these nine building designs only range between 10% and 15%.

Chapter 9: CONCLUSIONS AND RECOMMENDATIONS

An emphasis on the topic of sustainability is essential for the future. The aim of this study is to contribute, even if only slightly, to improving the understanding and implementation of sustainability strategies.

Internationally, as well as in South Africa, the construction industry contributes a great deal of harmful emissions and pollutants to the environment. It is therefore important that the industry and practices be moulded and adjusted to support efforts of sustainability, in whatever capacity possible.

One such strategy is through the assessment and optimisation of building structures to be more environmentally friendly. Currently the only official rating system in South Africa is the points-based Green Star SA rating tool. A more in-depth analysis might yield more useful results, and it was therefore decided to create a customised, analysis-oriented method for the analysis of buildings in the South African environment.

This life cycle assessment tool was designed to determine the environmental impact of a building envelope throughout all three life cycle phases: pre-use, use, and end-of-life. The environmental impact is measured in five different environmental impact categories, namely carbon footprint, acidification potential, eutrophication potential, resource depletion, and waste generation.

The pre-use and end-of-life phases had already been defined and tested, leaving only the use phase to be developed in order to complete the LCA. The use phase was developed in two components: maintenance and operation. The definition of the operation component limits the simplest, full applicability of this LCA to homes with constant mechanical ventilation.

The LCA was used to assess nine different buildings—one reference building, designed to meet the minimum requirements of the SANS 10400-XA, and eight variations of that building, where the only variable was the external walling system.

9.1. THE PROPOSED LCA AS AN ANALYSIS TOOL

Through the application of the LCA tool to the reference design building, the extent of the proposed LCA's capabilities as an analysis tool was considered.

Individual, quantified results were obtained for each of the five EI categories. These results were analysed in terms of the contribution of each building component to the whole impact. This type of analysis allows for the understanding of how each component of the building contributes to the various environmental impacts, and therefore gives insight into where and how changes can be applied to improve the environmental impact of the building as a whole.

9.2. THE PROPOSED LCA AS AN COMPARATIVE AND OPTIMISATION TOOL

Using the reference building as a baseline, the LCA was then used to examine the alternative external wall designs and so determine the changes in the environmental impact with the change of the external walling systems. A general trend (with a few exceptions) emerged: as the thermal properties of the external walling system improved, the need to use energy to heat and cool the building lessened. So, even though in most cases the environmental impact caused by the materials used in the building envelope increased marginally, the net outcome due to the lowered energy usage was in most cases a significant decrease in the environmental impact.

Another general trend also developed: as the R-value of the external walling system increased, the first four environmental impact categories showed a decrease. The main exception, Waste Generation (EI_5) was expected, as the materials used in construction generally increased with the change in the external walling system. Waste generation is also the only impact category that is almost negligibly affected by energy usage.

9.3. Overall Conclusions and Recommendations

It is important to note that these results and trends only apply to homes where mechanical ventilation is used consistently to regulate the temperature to the specified range prescribed in the SANS 10400-XA. This is in itself a highly unlikely scenario in most homes, and a simple sensitivity already shows that the thermal comfort of the occupants can be improved by moving the prescribed temperature range slightly higher (at least for a home built in the Cape Town area).

This revelation emphasises the need for local values to replace nationally-selected regulations. The climatic situation varies drastically across the South African landscape, and therefore homes cannot be held to the same standard of conditions across the country. If a specific temperature range is to be prescribed, it must be one that provides decent thermal comfort to occupants within the region where the home is built.

This leads to another fact—if the thermal comfort range differs from region to region, then so do the needs for the thermal capacities of the homes. Homes in regions that reach below-zero temperatures, for example, would need much greater thermal protection than homes in areas that maintain a fairly moderate temperature range. Linking this to the R-value of the different components of the building would mean that there would also be a need for localised R-value requirements, instead of the nationally required minimums that stand to date.

This is especially important in homes that are not specifically included in this study. A vast amount of homes in this country cannot afford heating or cooling, even though they may drastically need it. What is the purpose of a home if not to shelter its occupants from the elements? It is therefore important to determine the optimal minimum thermal requirements of structural elements, specific to individual regions and their climates.

Other important points to be considered are the importance of reuse/recycling strategies in the structural industry, as well as the use of alternative building systems. Decent reuse/recycling strategies can make a noticeable difference in the end-of-life phase, particularly in relation to Waste Generation (EI_5).

On a final note, strict regulations regarding the implementation of sustainability strategies in the structural industry are also essential. It is important to realise that even if the regulations and codes are perfected, they will be useless if they are not enforced.

Life cycle assessment can be an invaluable tool to support the construction industry in the optimisation of buildings. But the industry first needs to accept the responsibility of sustainability as an essential consideration in design and implementation, and they must be amenable to change in order to assist it.

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Appendix A: PROPOSED REFERENCE DESIGN DETAILS

A1: Monthly Bond Calculation

Calculation for Maximum Monthly Bond of Four-Person Household on Minimum Quintile 5 Income

Minimum Per Capita Monthly Household Income	R 3 997.00
Average Household Size	4
Minimum Monthly Household Income	R 15 988.00
Minimum Annual Household Income	R 191 856.00

CASE 1: Income from One Person

Annual Income	R 191 856.00		
	R 70 700.00	0%	R 0.00
	R 103 850.00	18%	R 18 693.00
	R 17 306.00	25%	R 4 326.50
Total Annual Tax[1]			R 23 019.50
Monthly UIF[2]		1%	R 148.72
Annual UIF			R 1 784.64
Annual Household Disposable Income			R 167 051.86
Total Monthly Household Disposable Income			R 13 920.99
Household debt/Disposable Income[3]			0.75
Mortgage Debt/Non-mortgage Debt[3]			1
Montly Mortgage			R 5 220.37

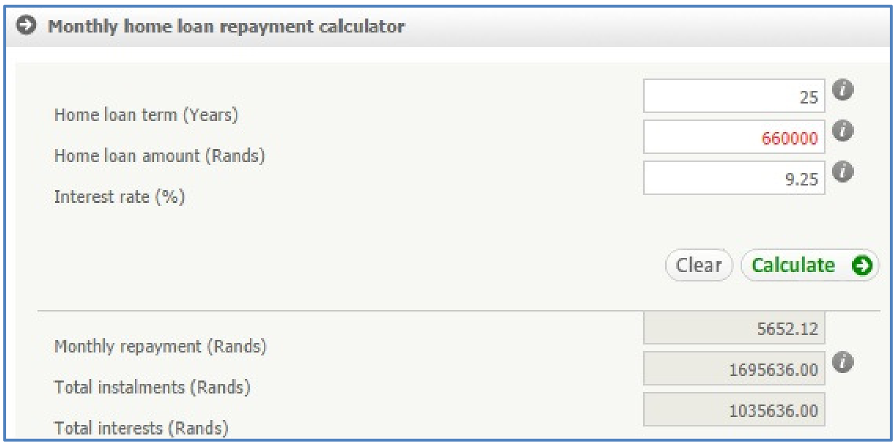
CASE 2: Equal Income from 2 People

Annual Income (pp)	R 95 928.00		
	R 70 700.00	0%	R 0.00
	R 25 228.00	18%	R 4 541.04
	R 0.00	25%	R 0.00
Total Annual Tax[1]			R 4 541.04
Monthly UIF[2]		1%	R 79.94
Annual UIF (pp)			R 959.28
Annual Household Disposable Income (pp)			R 90 427.68
Total Monthly Household Disposable Income			R 15 071.28
Household debt/Disposable Income[3]			0.75
Mortgage Debt/Non-mortgage Debt[3]			1
Montly Mortgage			R 5 651.73

THEREFORE Maximum Monthly Bond of Four-Person Household on Minimum Quintile 5 Income: R 5 651.73

1. Tax calculated in accordance with SARS (2014a).
2. UIF calculated in accordance with SARS (2014b).
3. Ratios simplified from SARB (2013:10).

A2: Total Bond



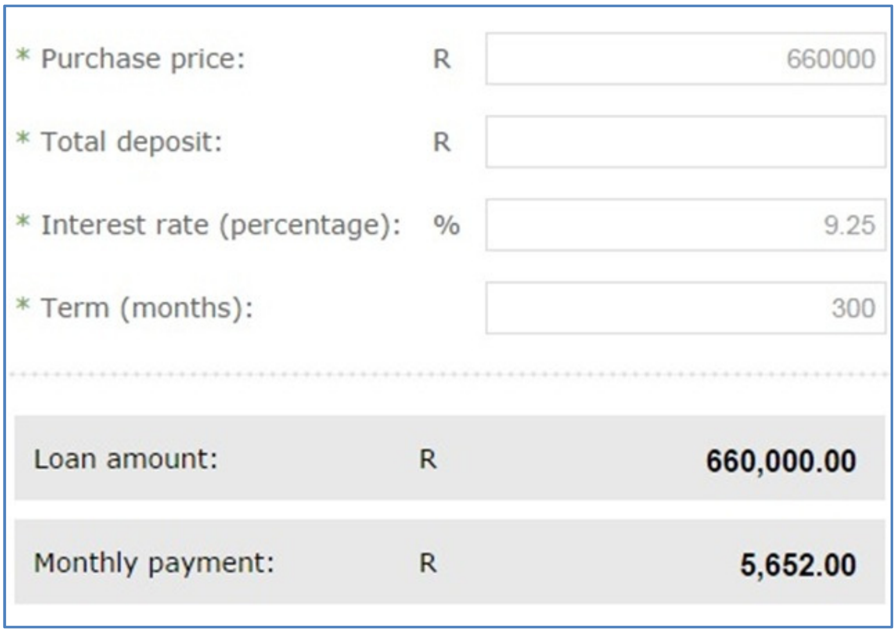
Monthly home loan repayment calculator

Home loan term (Years)	25
Home loan amount (Rands)	660000
Interest rate (%)	9.25

Clear Calculate

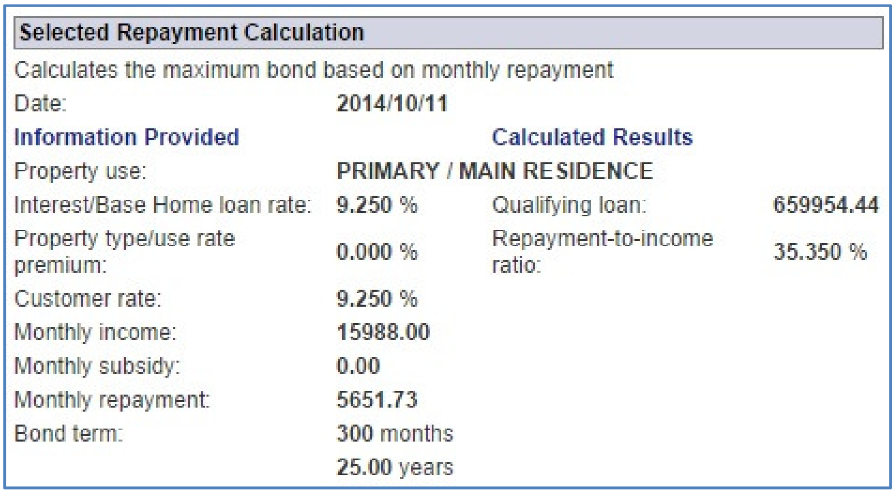
Monthly repayment (Rands)	5652.12
Total instalments (Rands)	1695636.00
Total interests (Rands)	1035636.00

FIGURE A-1: MONTHLY HOME LOAN REPAYMENT CALCULATOR, ABSA (2014)



* Purchase price:	R	660000
* Total deposit:	R	
* Interest rate (percentage):	%	9.25
* Term (months):		300
Loan amount:	R	660,000.00
Monthly payment:	R	5,652.00

FIGURE A-2: BOND REPAYMENT CALCULATOR, NEDBANK (2014)



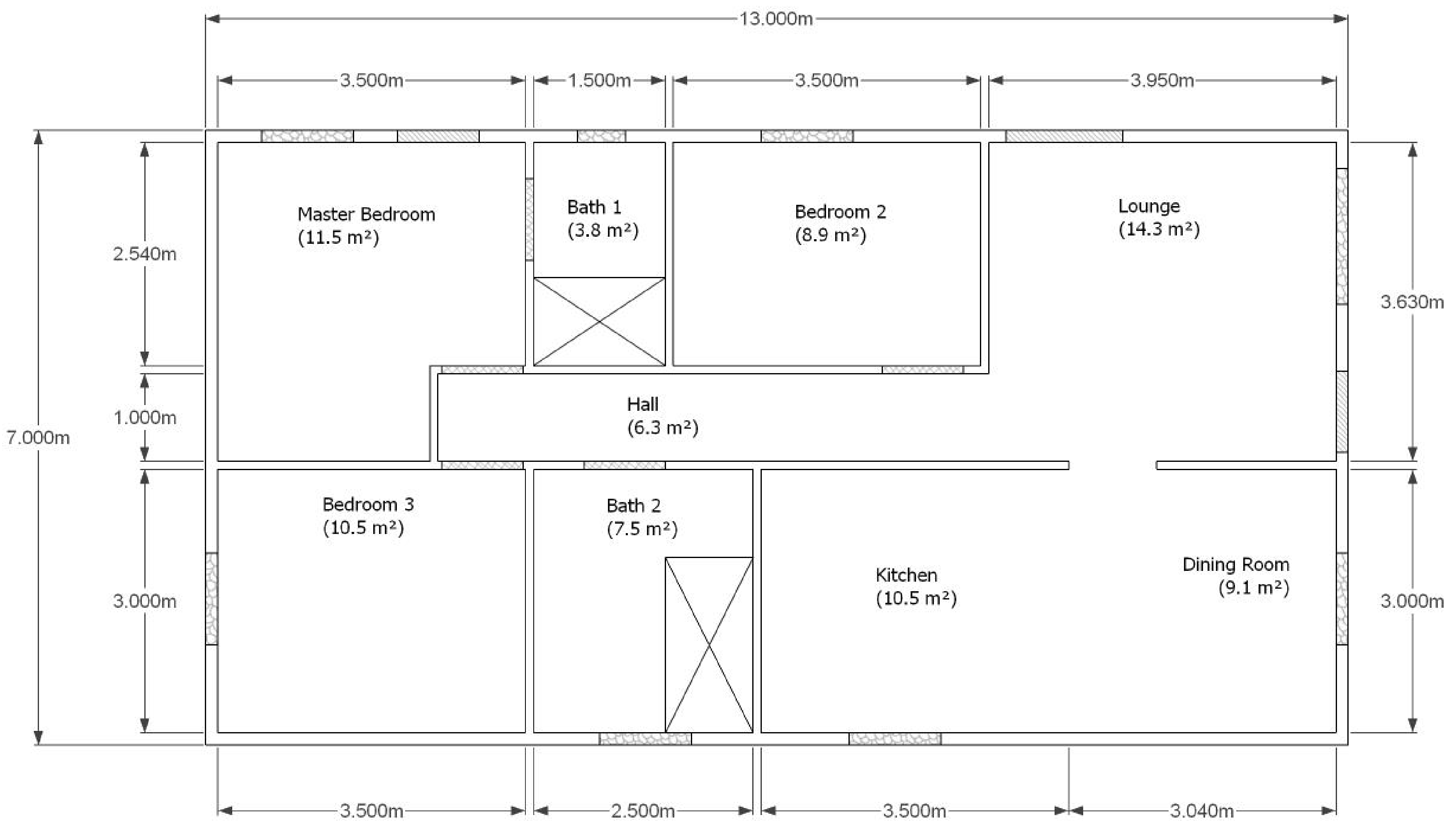
Selected Repayment Calculation

Calculates the maximum bond based on monthly repayment

Date:	2014/10/11		
Information Provided		Calculated Results	
Property use:	PRIMARY / MAIN RESIDENCE		
Interest/Base Home loan rate:	9.250 %	Qualifying loan:	659954.44
Property type/use rate premium:	0.000 %	Repayment-to-income ratio:	35.350 %
Customer rate:	9.250 %		
Monthly income:	15988.00		
Monthly subsidy:	0.00		
Monthly repayment:	5651.73		
Bond term:	300 months		
	25.00 years		

FIGURE A-3: BOND CALCULATOR, STANDARD BANK (2014)

A3: Proposed Layout



A4: Basic Dimensions of Proposed Reference Building

Roof			
	Roof base length	7.4	m
	Roof height	1.167	m
	Roof slope length (one side)	3.880	m
	Roof slope length (both sides)	7.759	m
	Roof slope area	100.869	m^2
Exterior perimeter			
	Unoccupied floor area	91	m^2
	Occupied floor area	85.5	m^2
	Exterior wall perimeter	40	m
	Height from 2.4m to rooftop	1.104	m
	Exterior wall area (E/W walls)	20.66	m^2
	Exterior wall area (N/S walls)	31.20	m^2
	Total exterior wall area	103.72	m^2
	Total exterior wall openings	13.93	m^2
	Net exterior wall area	89.80	m^2
Internal walls			
	Internal wall length	33.06	m
	Total internal wall area	79.34	m^2
	Total internal wall openings	9.78	m^2
	Net internal wall area	69.57	m^2
	Total width & lengths under int walls (for ease of foundation design)	61	m

A5: Opening Calculations

	Amount	Interior		Exterior		Area	TOTAL
		W (m)	H (m)	W (m)	H (m)	(m^2)	(m^2)
DOORS[1]							
Interior (no cills)	5	0.813	2.032	0.925	2.114	1.955	9.777
Exterior (with cills)							
Front (OI)	1	0.813	2.032	0.925	2.130	1.970	1.970
F Lounge (OO)	1	1.210	2.032	1.322	2.118	2.800	2.800
F Bedroom (OO)	1	0.813	2.032	0.925	2.118	1.959	1.959
WINDOWS[1]							
F Bathroom 1	1			0.545	0.600	0.327	0.327
F Bathroom 2	1			1.045	0.600	0.627	0.627
F Bedrooms	3			1.045	0.900	0.941	2.822
F Kitchen	1			1.045	0.600	0.627	0.627
F Dining	1			1.045	0.900	0.941	0.941
F Lounge	1			1.545	1.200	1.854	1.854
TOTAL FENESTRATION							**11.956**
TOTAL OPENINGS							**13.926**

Total Net Floor Area (m^2) **85.5**

Fenestration as Percentage of Net Floor Area **13.98%**

This is less than 15% and therefore complies with SANS 10400-XA (2011:10).

1. All internal and external measurements taken from Swartland (2012).

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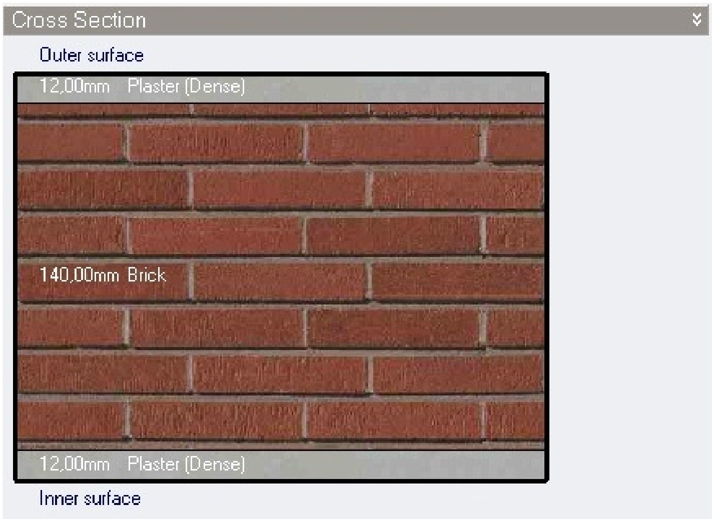
Appendix B: EXTERNAL WALL DESIGN DETAILS

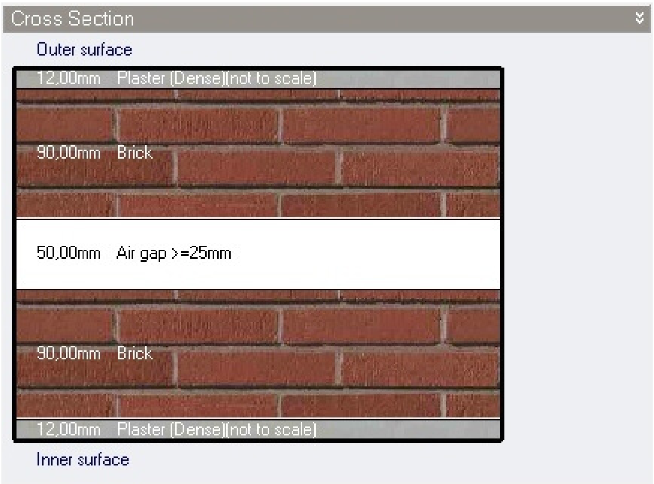
B1. External Walling System 01: Reference Design (Single leaf hollow concrete masonry)

Name	Reference Design (Single Leaf Hollow Concrete Masonry)
Type	Standard Construction (South Africa)
General description	Single leaf hollow concrete brick wall with 12mm plaster on either side.
Bill of Quantities	DPC 145mm hollow concrete bricks (with the top two courses filled with concrete) Brickforce (at 400mm vertical distance) 12mm Plaster (internally & externally)
R-value	0.354 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 3 Outermost layer Material: Plaster (Dense) Thickness (m): 0.0200 ☐ Bridged? Layer 2 Material: Concrete blocks/tiles - block Thickness (m): 0.1400 ☐ Bridged? Innermost layer Material: Plaster (Dense) Thickness (m): 0.0200 ☐ Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2.152 Radiative heat transfer coefficient (W/... 5.540 Surface resistance (m2-K/W) 0.130 Outer surface Convective heat transfer coefficient (W... 19.870 Radiative heat transfer coefficient (W/... 5.130 Surface resistance (m2-K/W) 0.040 No Bridging U-Value surface to surface (W/m2-K) 5.444 R-Value (m2-K/W) 0.354 **U-Value (W/m2-K) 2.827**

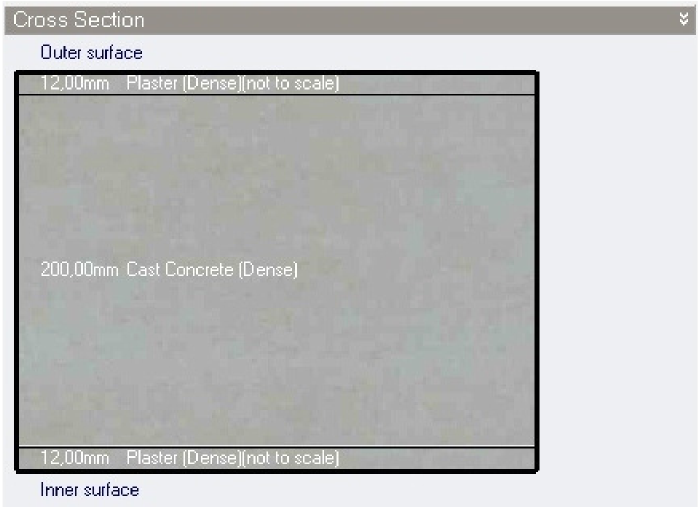
B2. External Walling System 02: Single Leaf Clay Masonry

Name	Single Leaf Brick Wall (140mm)
Type	Standard Construction (South Africa)
General description	Single leaf clay brick wall with 12mm plaster on either side.
Bill of Quantities	DPC 140mm Clay bricks Brickforce (at 400mm vertical distance) 12mm Plaster (internally & externally)
R-value	0.412 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 3 Outermost layer Material: Plaster (Dense) Thickness (m): 0,0120 ☐ Bridged? Layer 2 Material: Brick Thickness (m): 0,1400 ☐ Bridged? Innermost layer Material: Plaster (Dense) Thickness (m): 0,0120 ☐ Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2,152 Radiative heat transfer coefficient (W/... 5,540 Surface resistance (m2-K/W) 0,130 Outer surface Convective heat transfer coefficient (W... 19,870 Radiative heat transfer coefficient (W/... 5,130 Surface resistance (m2-K/W) 0,040 No Bridging U-Value surface to surface (W/m2-K) 4,125 R-Value (m2-K/W) 0,412 **U-Value (W/m2-K) 2,425**

B3. External Walling System 03: Double Leaf Brick Cavity Wall

Name	Double Leaf Brick Cavity Wall
Type	Standard Construction (South Africa)
General description	Double leaf clay brick cavity wall with 12mm plaster on either side.
Bill of Quantities	DPC 90mm Clay bricks Brickforce (at 400mm vertical distance) 12mm Plaster (internally & externally)
R-value	0.648 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 5 Outermost layer Material: Plaster (Dense) Thickness (m): 0,0120 Bridged? Layer 2 Material: Brick Thickness (m): 0,0900 Bridged? Layer 3 Material: Air gap >=25mm Thickness (not used in thermal calcs...: 0,0500 Layer 4 Material: Brick Thickness (m): 0,0900 Bridged? Innermost layer Material: Plaster (Dense) Thickness (m): 0,0120 Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W...: 2,152 Radiative heat transfer coefficient (W/...: 5,540 Surface resistance (m2-K/W): 0,130 Outer surface Convective heat transfer coefficient (W...: 19,870 Radiative heat transfer coefficient (W/...: 5,130 Surface resistance (m2-K/W): 0,040 No Bridging U-Value surface to surface (W/m2-K): 2,092 R-Value (m2-K/W): 0,648 **U-Value (W/m2-K): 1,543**

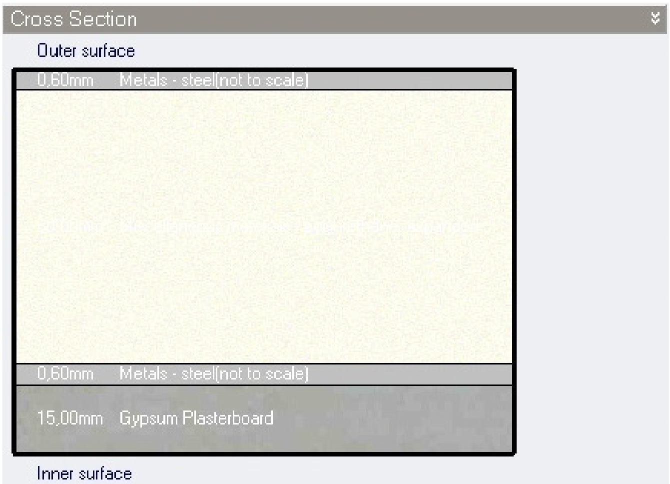
B4. External Walling System 04: Cast Concrete Wall

Name	Cast Concrete Wall
Type	Standard Construction (South Africa)
General description	200mm cast concrete wall with 12mm plaster on either side.
Bill of Quantities	DPC 200mm Cast concrete 12mm Plaster (internally & externally)
R-value	0.361 (does not comply with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 3 Outermost layer Material: Plaster (Dense) Thickness (m): 0,0120 Bridged? Layer 2 Material: Cast Concrete (Dense) Thickness (m): 0,2000 Bridged? Innermost layer Material: Plaster (Dense) Thickness (m): 0,0120 Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2,152 Radiative heat transfer coefficient (W/... 5,540 Surface resistance (m2-K/W) 0,130 Outer surface Convective heat transfer coefficient (W... 19,870 Radiative heat transfer coefficient (W/... 5,130 Surface resistance (m2-K/W) 0,040 No Bridging U-Value surface to surface (W/m2-K) 5,240 R-Value (m2-K/W) 0,361 **U-Value (W/m2-K) 2,771**

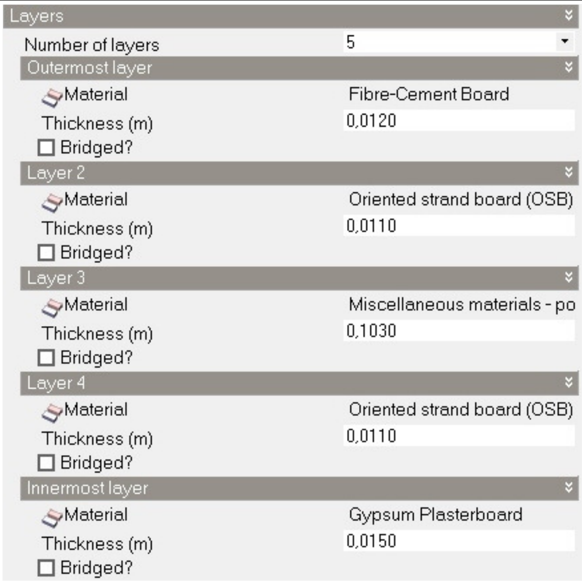
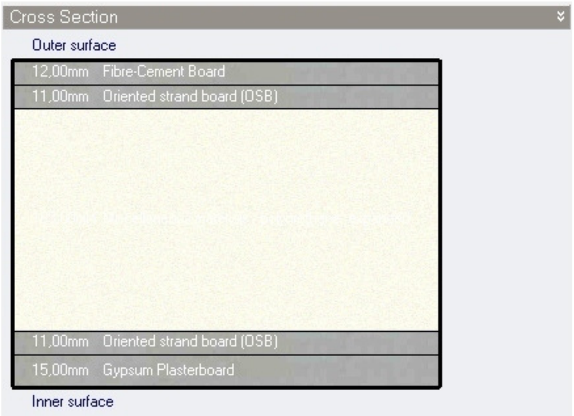
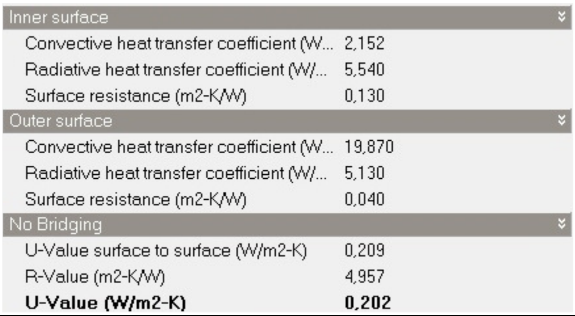
B5. External Walling System 05: Innovida Building System

Name	Innovida Building System
Type	Alternative Building System (South Africa)
Agrément Certificate	2009/M55
General description	An expanded polyurethane core encapsulated by two sheets of resin-saturated glass fibre.
Bill of Quantities	DPC 60mm Expanded polyurethane core 2mm resin-saturated glass fibre sheet (internally & externally) 70x60x2mm glass fibre base rail
R-value	2.890 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 3 Outermost layer Material: Glass fibre/wool - wool, resin Thickness (m): 0,0020 Bridged? Layer 2 Material: Miscellaneous materials - po Thickness (m): 0,0600 Bridged? Innermost layer Material: Glass fibre/wool - wool, resin Thickness (m): 0,0020 Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2,152 Radiative heat transfer coefficient (W/... 5,540 Surface resistance (m2-K/W) 0,130 Outer surface Convective heat transfer coefficient (W... 19,870 Radiative heat transfer coefficient (W/... 5,130 Surface resistance (m2-K/W) 0,040 No Bridging U-Value surface to surface (W/m2-K) 0,368 R-Value (m2-K/W) 2,890 **U-Value (W/m2-K) 0,346**

B6. External Walling System 06: Affordable Comfort Homes

Name	Affordable Comfort Homes
Type	Alternative Building System (South Africa)
Agrément Certificate	2005/319
General description	Two sheets of galvanised sheet steel encapsulating an expanded polyurethane core, with Rhinowall internal cladding.
Bill of Quantities	DPC 60mm Expanded polyurethane core 0.6mm galvanised sheet steel (internally & externally) 15mm gypsum plasterboard 52 x 52 x 2mm galvanised steel base rail
R-value	2.839 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 4 Outermost layer Material: Metals - steel Thickness (m): 0,0006 Bridged? Layer 2 Material: Miscellaneous materials - po Thickness (m): 0,0600 Bridged? Layer 3 Material: Metals - steel Thickness (m): 0,0006 Bridged? Innermost layer Material: Gypsum Plasterboard Thickness (m): 0,0150 Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2,152 Radiative heat transfer coefficient (W/... 5,540 Surface resistance (m2-K/W) 0,130 Outer surface Convective heat transfer coefficient (W... 19,870 Radiative heat transfer coefficient (W/... 5,130 Surface resistance (m2-K/W) 0,040 No Bridging U-Value surface to surface (W/m2-K) 0,375 R-Value (m2-K/W) 2,839 **U-Value (W/m2-K) 0,352**

B7. External Walling System 07: MG Sip Building System

Name	MG Sip Building System
Type	Alternative Building System (South Africa)
Agrément Certificate	2010/370
General description	A polyurethane core encapsulated by two layers of thick oriented strand board (OSB), clad internally with gypsum plasterboard and externally with medium density Nutek board.
Bill of Quantities	103mm polyurethane core 15mm gypsum plasterboard 11mm oriented strand board (internally & externally) 12mm fibre-cement board 127x52x2mm steel base rail 38x38mm timber brandering, at 300mm centres, both sides DPC
R-value	4.957 (complies with SANS 10400-XA)
DesignBuilder Layers	
DesignBuilder Image	
DesignBuilder Calculations	

B8. External Walling System 08: Blast Building System

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<tr><td>Type</td><td>Alternative Building System (South Africa)</td></tr>
<tr><td>Agrément Certificate</td><td>2010/372</td></tr>
<tr><td>General description</td><td>A thick sprayed concrete wall with internal magboard cladding and external plaster rendering.</td></tr>
<tr><td>Bill of Quantities</td><td>DPC
90mm thick sprayed concrete
50x50x2.5mm weldmesh
6mm magboard (internal)
15mm plaster (external)
92x40x1.5mm zincalume base rail
90x40mm light gauge zincalume channel at top</td></tr>
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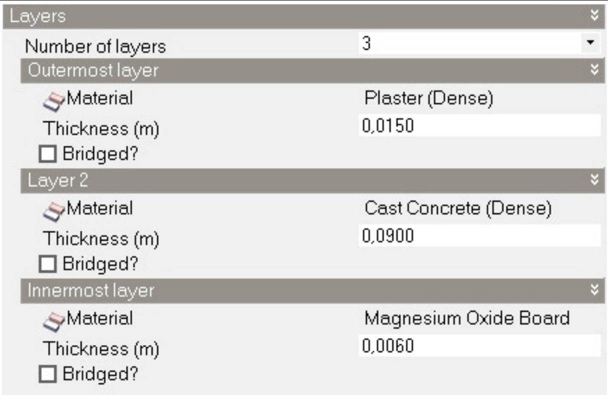
<tr><td>DesignBuilder Layers</td><td>
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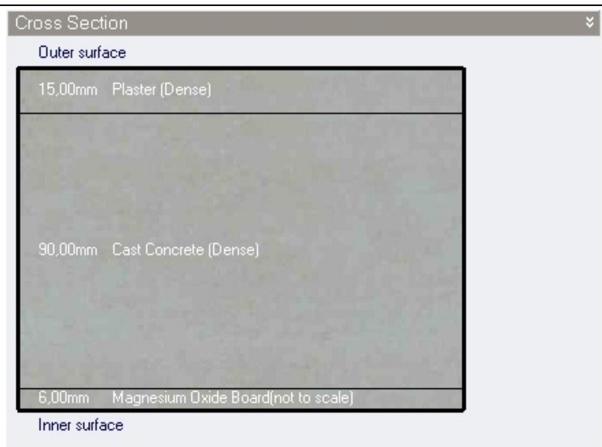
<tr><td>DesignBuilder Image</td><td>
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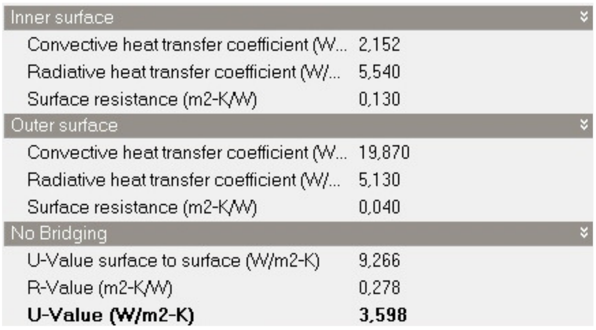
<tr><td>DesignBuilder Calculations</td><td>
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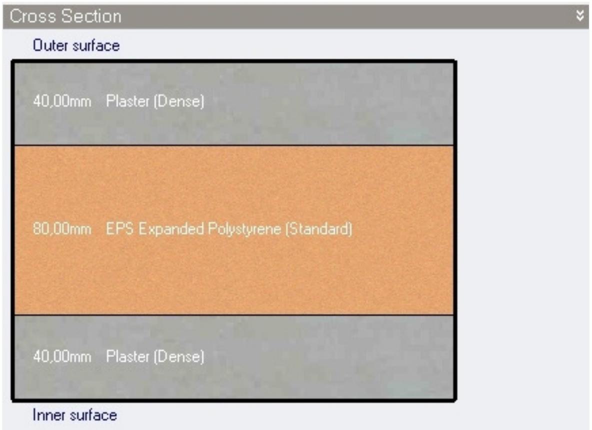
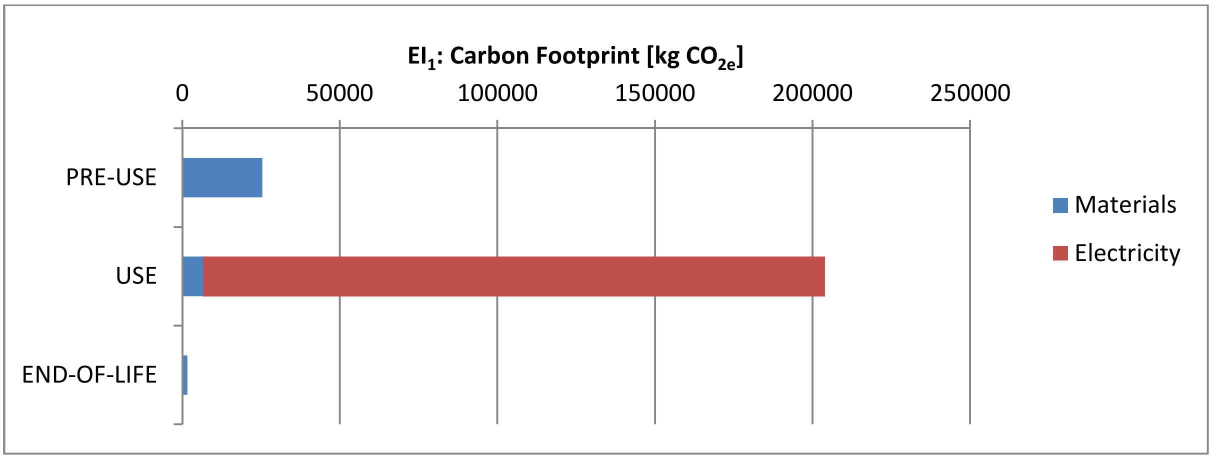
B9. External Walling System 09: Ikhaya Future House Building System

Name	Ikhaya Future House Building System
Type	Alternative Building System (South Africa)
Agrément Certificate	2007/331
General description	An expanded polystyrene (EPS) core surrounded by galvanised weldmesh and plaster.
Bill of Quantities	DPC 80mm expanded polystyrene (EPS) core 100x100x3.5mm galvanised steel weldmesh (both sides) 40mm plaster (internally and externally)
R-value	2.330 (complies with SANS 10400-XA)
DesignBuilder Layers	Layers Number of layers: 3 Outermost layer Material: Plaster (Dense) Thickness (m): 0,0400 Bridged? Layer 2 Material: EPS Expanded Polystyrene Thickness (m): 0,0800 Bridged? Innermost layer Material: Plaster (Dense) Thickness (m): 0,0400 Bridged?
DesignBuilder Image	
DesignBuilder Calculations	Inner surface Convective heat transfer coefficient (W... 2,152 Radiative heat transfer coefficient (W/... 5,540 Surface resistance (m2-K/W) 0,130 Outer surface Convective heat transfer coefficient (W... 19,870 Radiative heat transfer coefficient (W/... 5,130 Surface resistance (m2-K/W) 0,040 No Bridging U-Value surface to surface (W/m2-K) 0,463 R-Value (m2-K/W) 2,330 **U-Value (W/m2-K) 0,429**

Appendix C: Reference Building LCA Results

C1. Carbon Footprint Results



CARBON FOOTPRINT (EI1) OF REFERENCE BUILDING

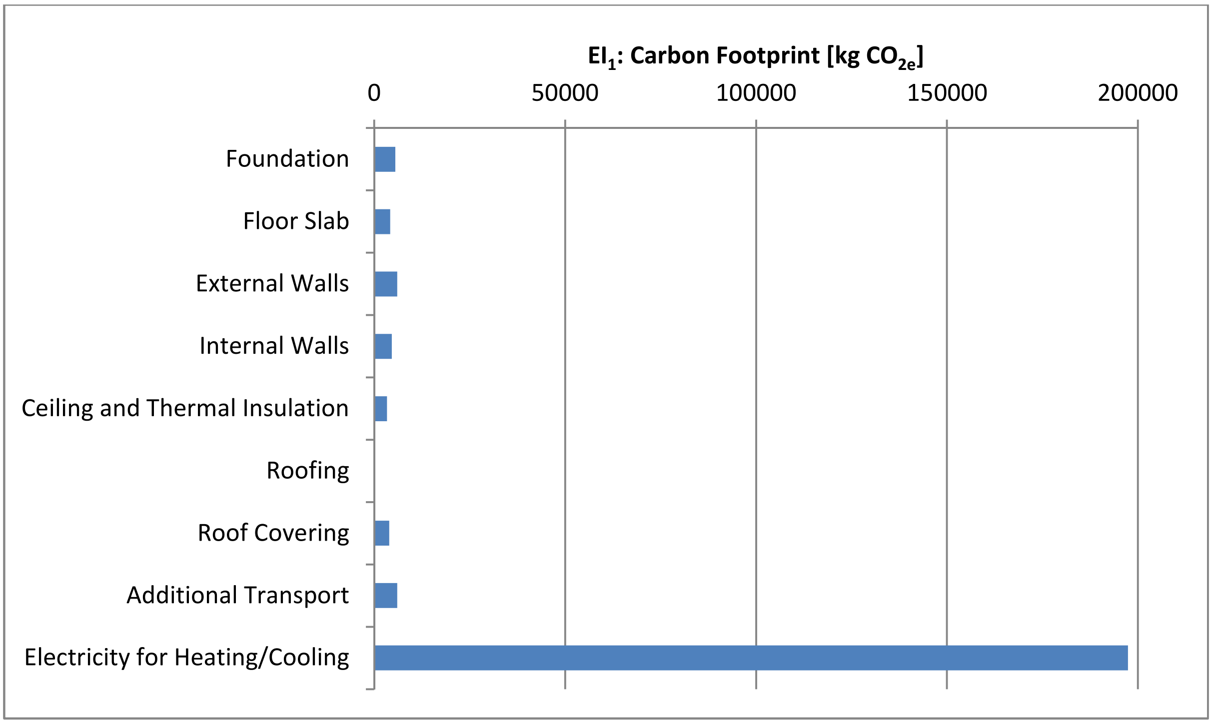


FIGURE C-1: CARBON FOOTPRINT (EI1) OF REFERENCE BUILDING - ALL COMPONENTS, FULL LIFE CYCLE

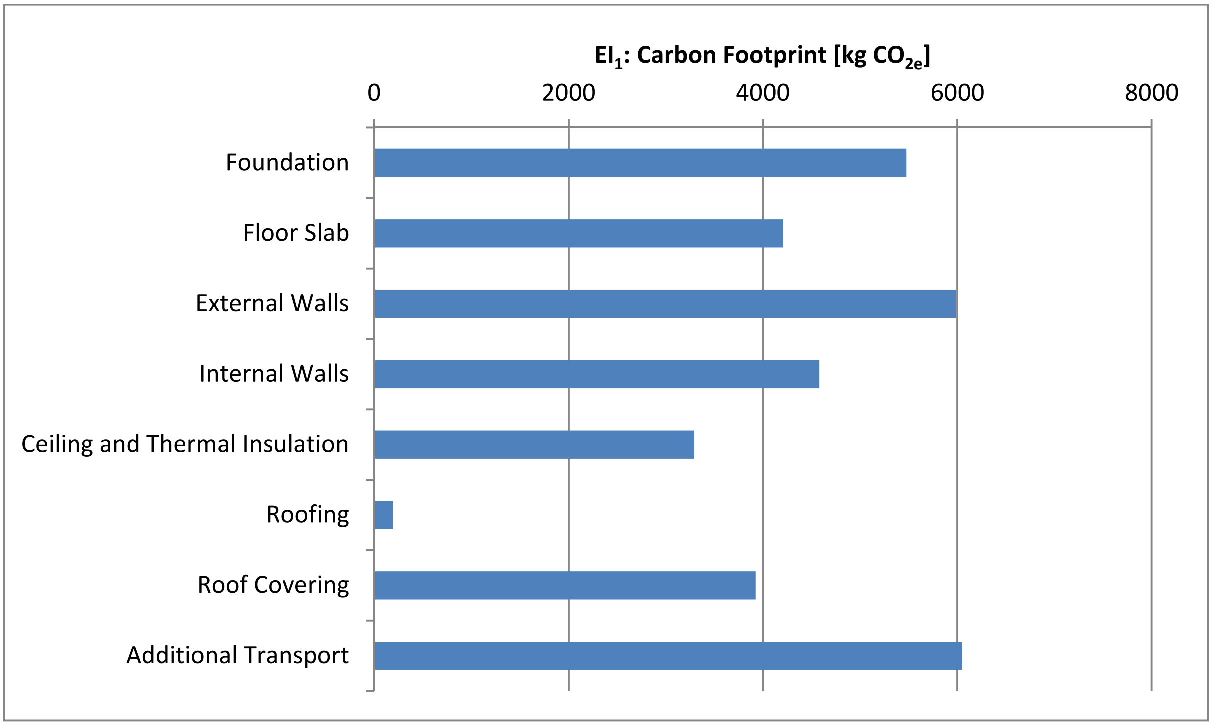


FIGURE C-2: CARBON FOOTPRINT (EI1) OF REFERENCE BUILDING - EXCL. ELECTRICITY, FULL LIFE CYCLE

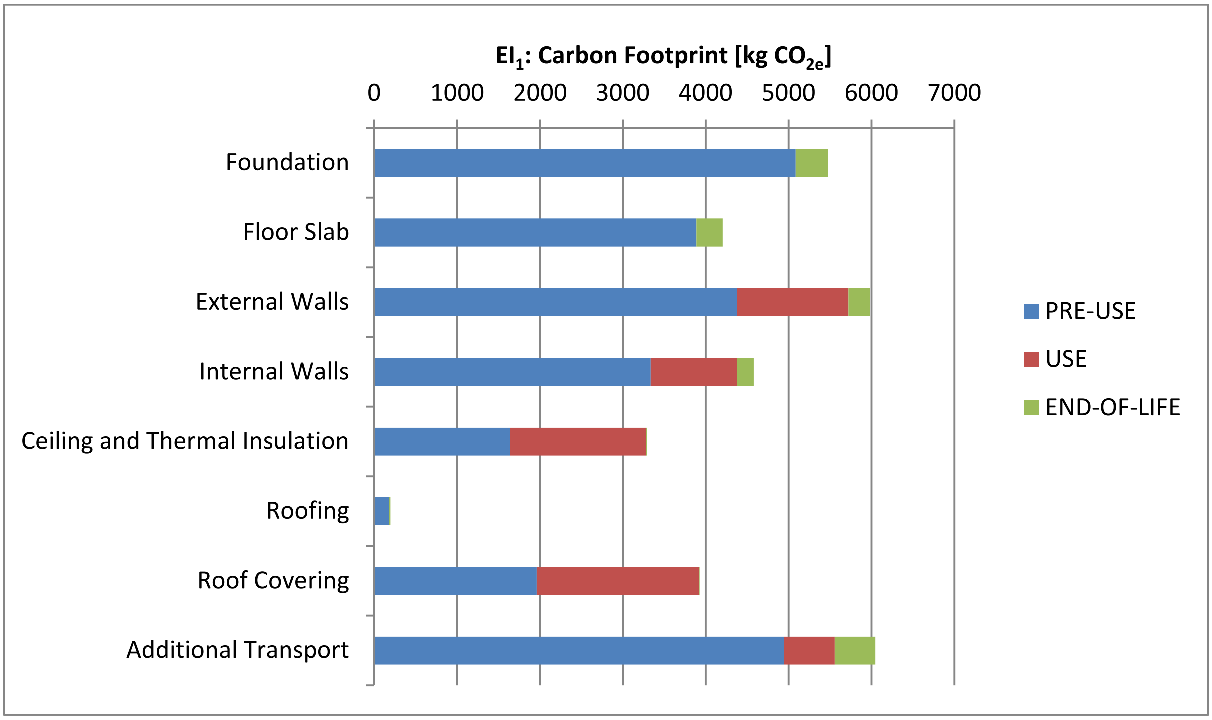


FIGURE C-3: CARBON FOOTPRINT (EI1) OF REFERENCE BUILDING – EXCL. ELECTRICITY, PER PHASE

C2. Acidification Potential Results

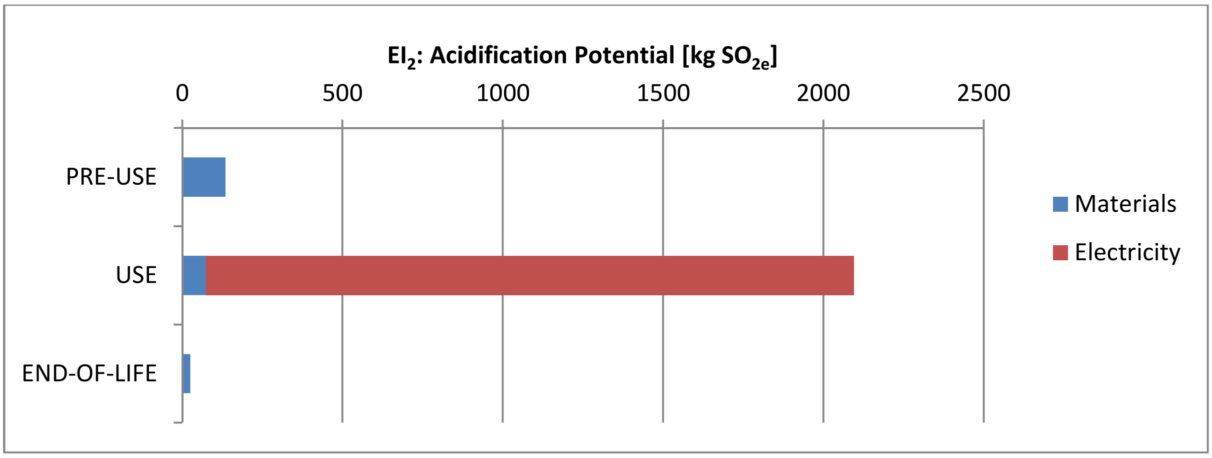


FIGURE C-4: ACIDIFICATION POTENTIAL (EI2) OF REFERENCE BUILDING

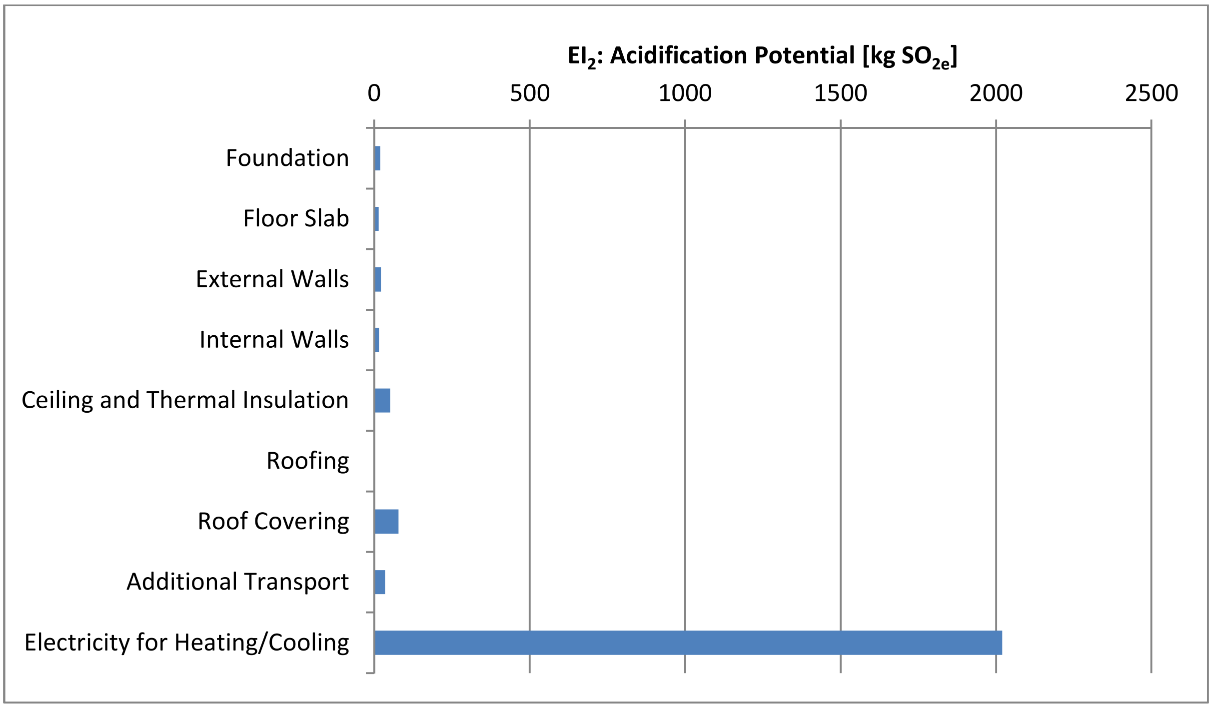


FIGURE C-5: ACIDIFICATION POTENTIAL (EI2) OF REFERENCE BUILDING - ALL COMPONENTS, FULL LIFE CYCLE

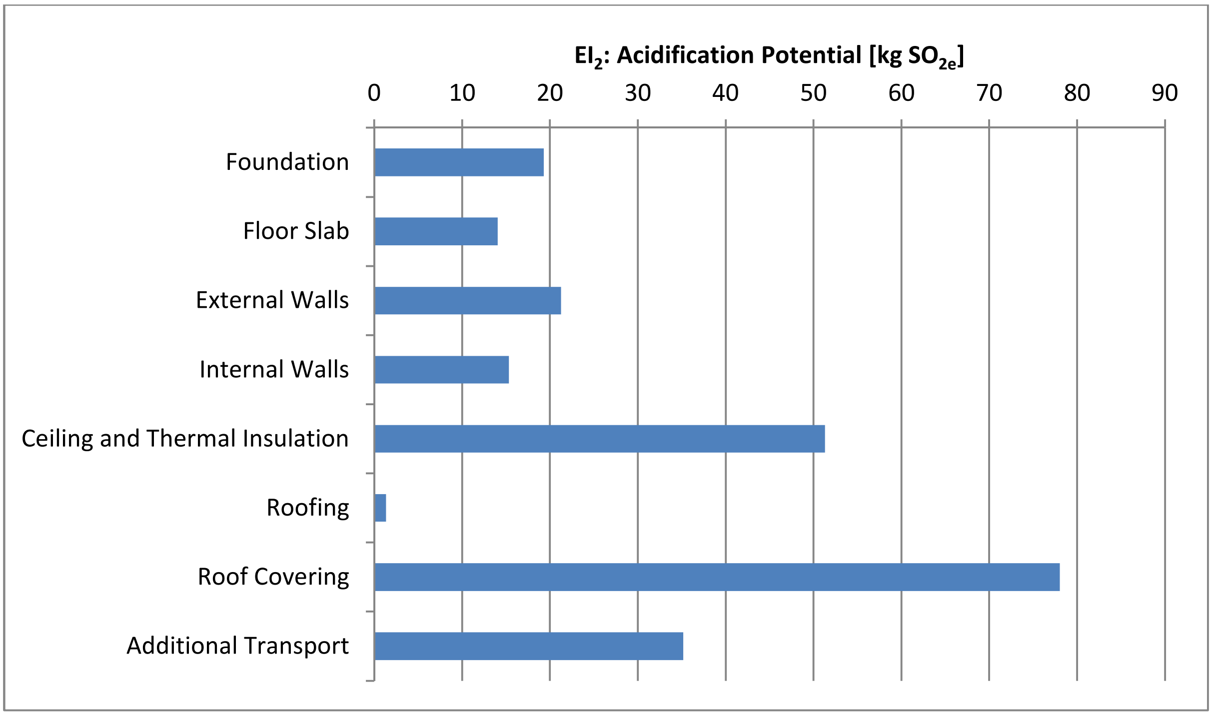


FIGURE C-6: ACIDIFICATION POTENTIAL (EI2) OF REFERENCE BUILDING - EXCL. ELECTRICITY, FULL LIFE CYCLE

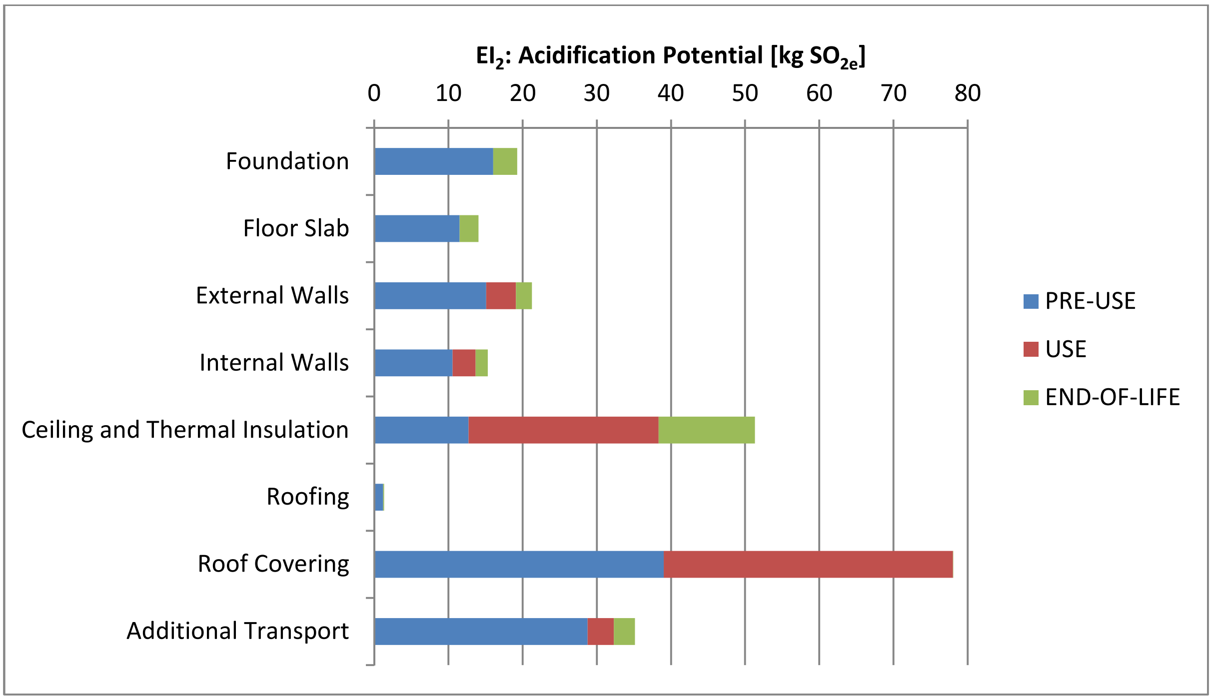


FIGURE C-7: ACIDIFICATION POTENTIAL (EI2) OF REFERENCE BUILDING – EXCL. ELECTRICITY, PER PHASE

C3. Eutrophication Potential Results

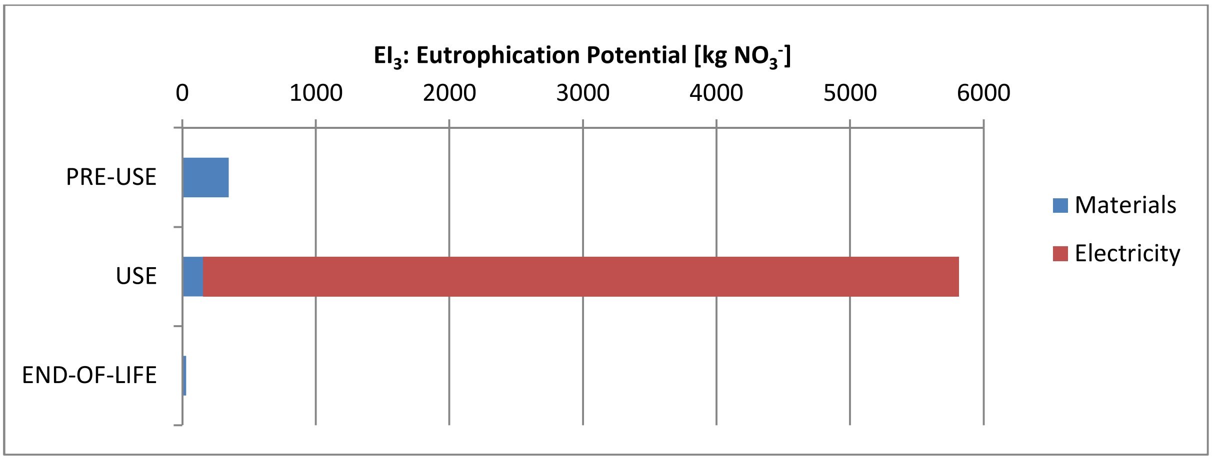


FIGURE C-8: EUTROPHICATION POTENTIAL (EI3) OF REFERENCE BUILDING

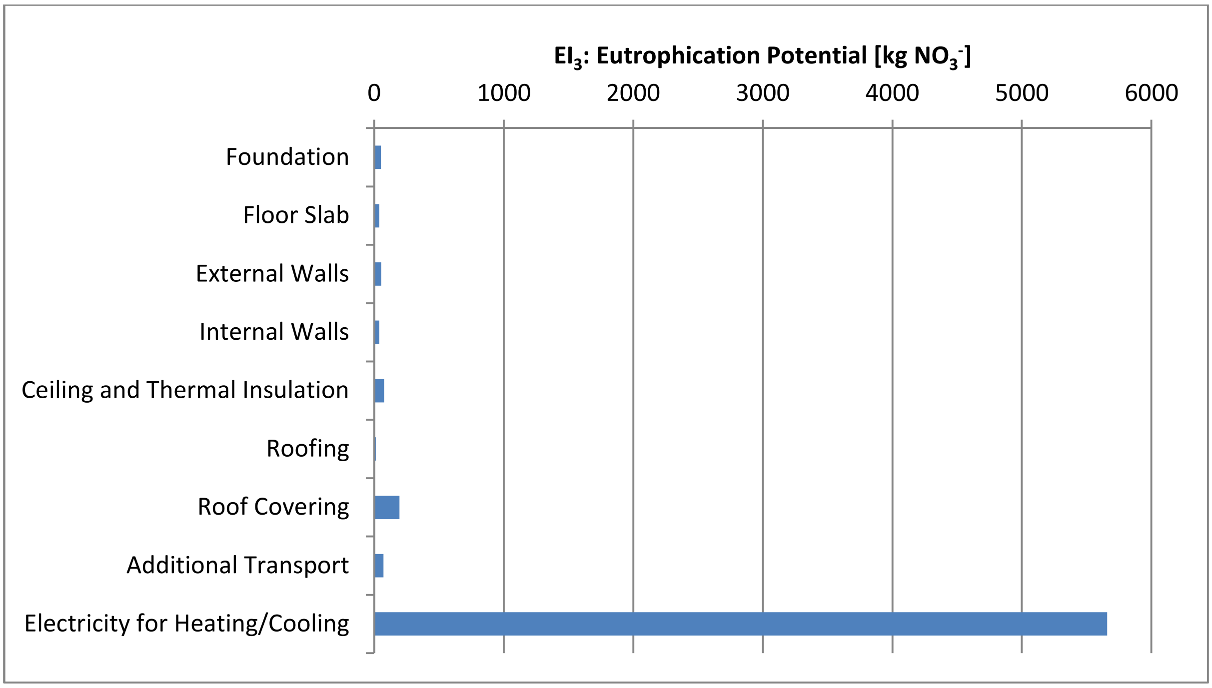


FIGURE C-9: EUTROPHICATION POTENTIAL (EI3) OF REFERENCE BUILDING - ALL COMPONENTS, FULL LIFE CYCLE

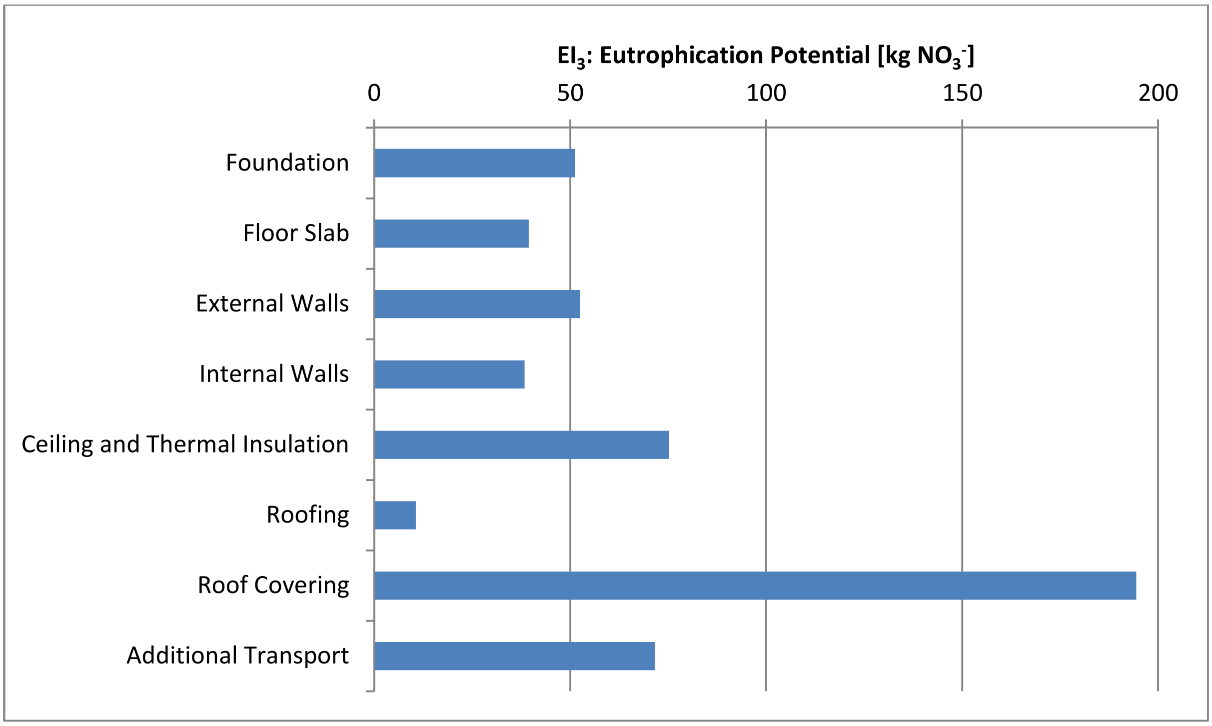


FIGURE C-10: EUTROPHICATION POTENTIAL (EI3) OF REFERENCE BUILDING - EXCL. ELECTRICITY, FULL LIFE CYCLE

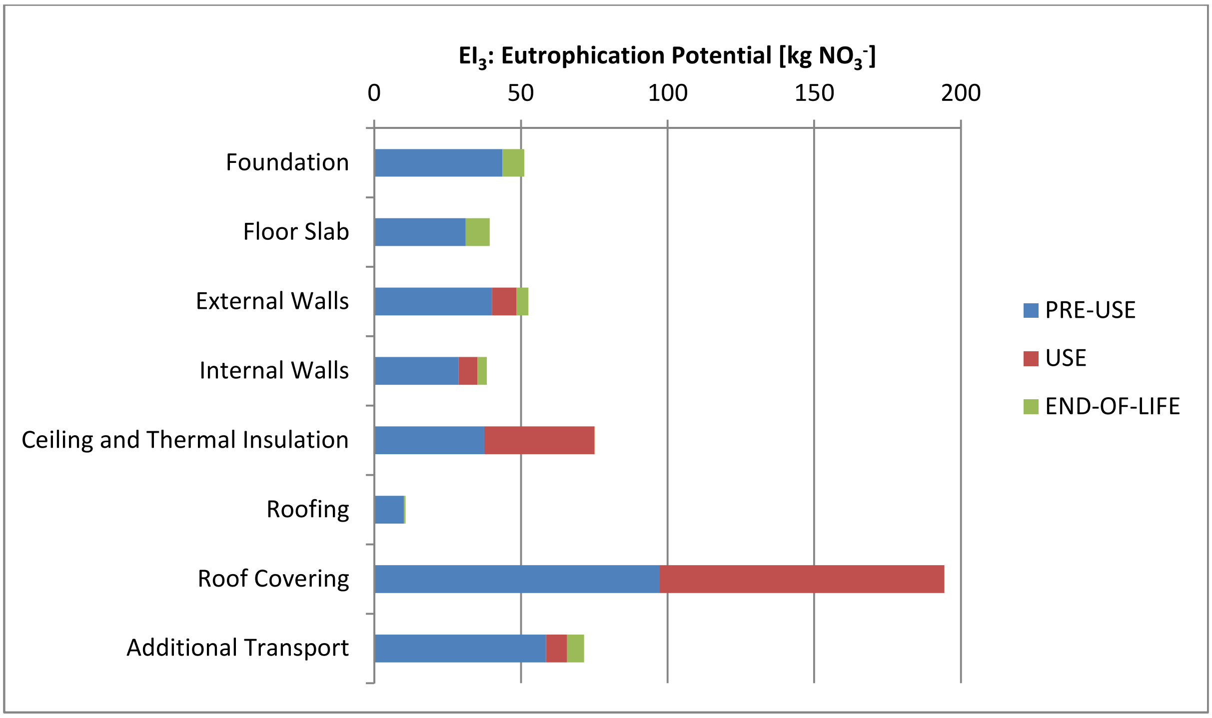


FIGURE C-11: EUTROPHICATION POTENTIAL (EI3) OF REFERENCE BUILDING – EXCL. ELECTRICITY, PER PHASE

C4. Resource Depletion Results

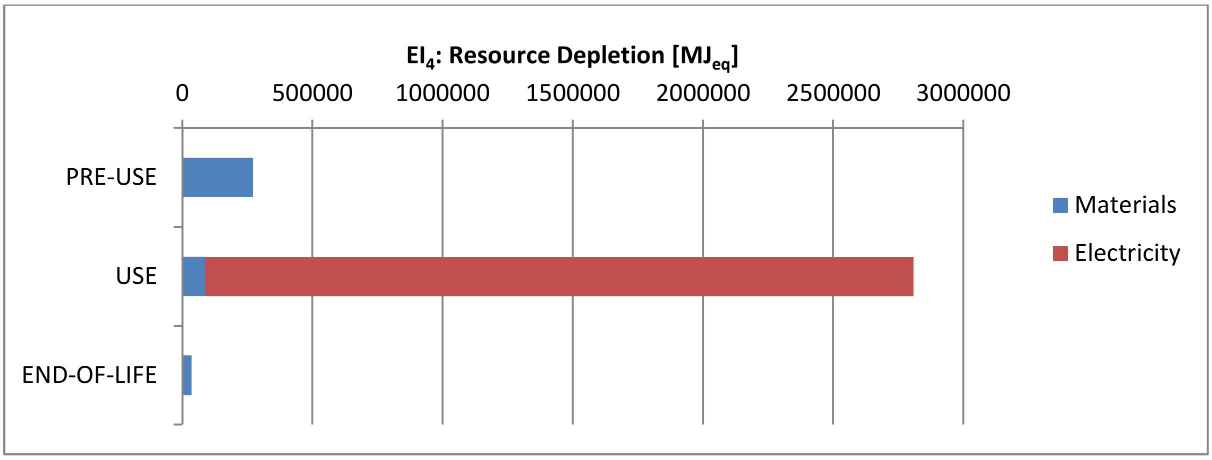


FIGURE C-12: RESOURCE DEPLETION (EI4) OF REFERENCE BUILDING

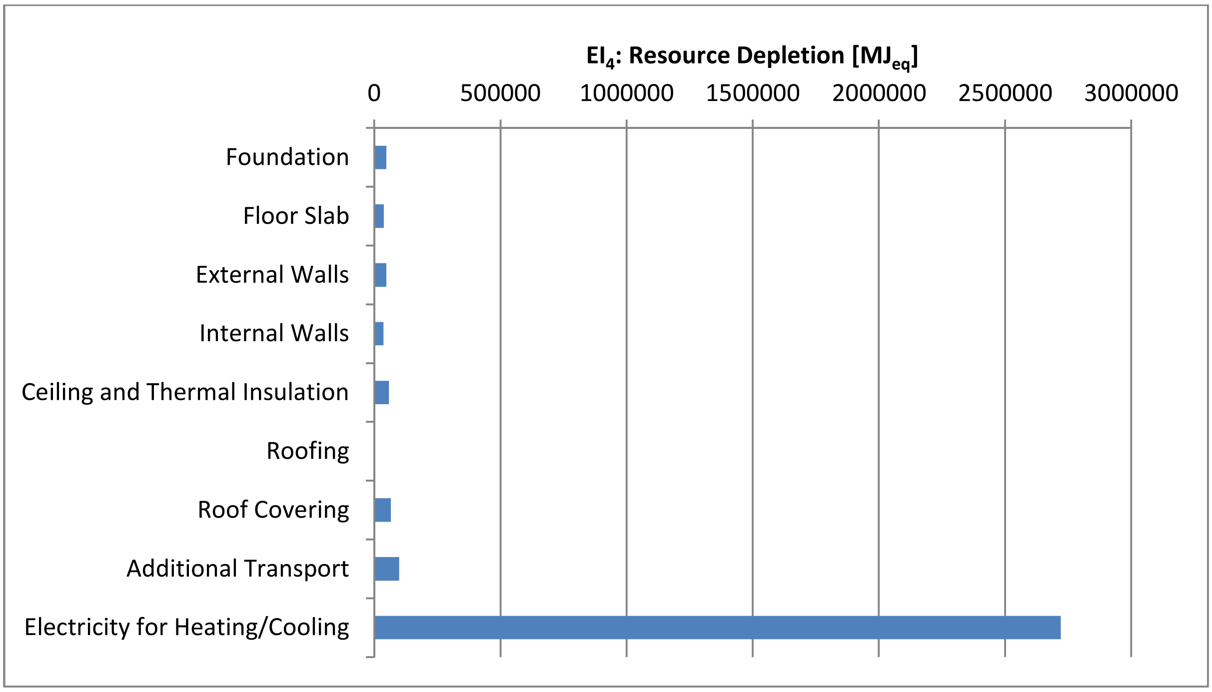


FIGURE C-13: RESOURCE DEPLETION (EI4) OF REFERENCE BUILDING - ALL COMPONENTS, FULL LIFE CYCLE

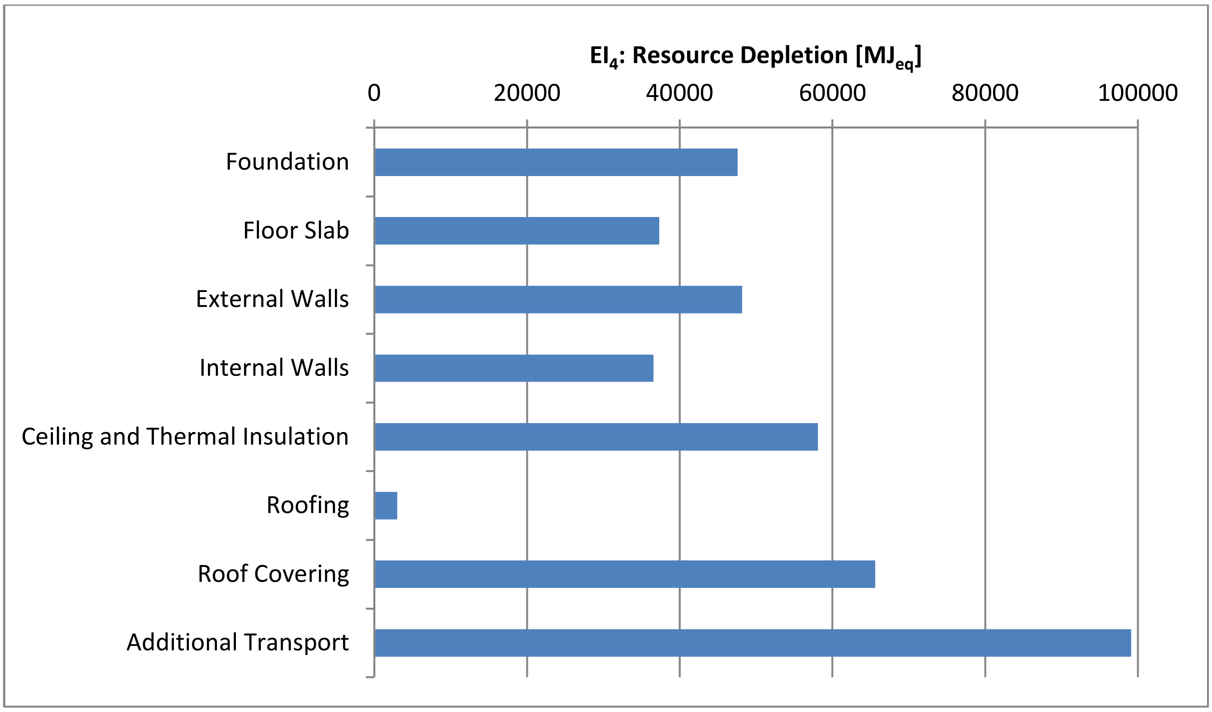


FIGURE C-14: RESOURCE DEPLETION (EI4) OF REFERENCE BUILDING - EXCL. ELECTRICITY, FULL LIFE CYCLE

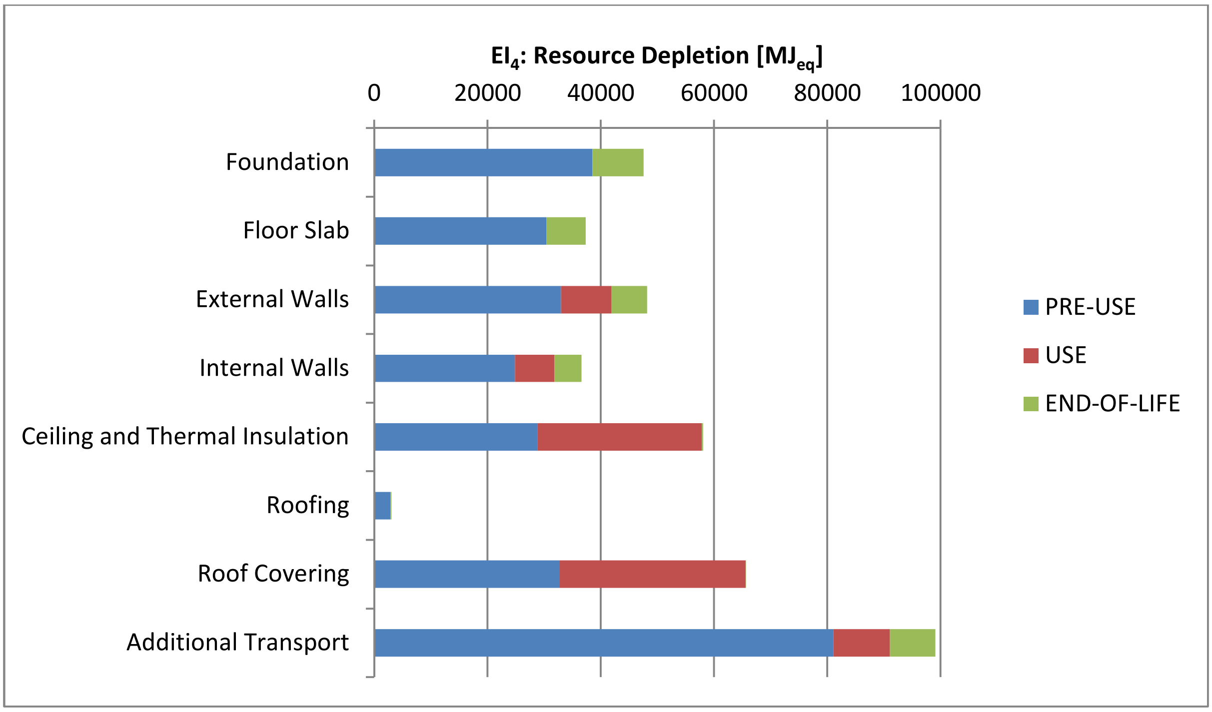


FIGURE C-15: RESOURCE DEPLETION (EI4) OF REFERENCE BUILDING – EXCL. ELECTRICITY, PER PHASE

C5. Waste Generation Results

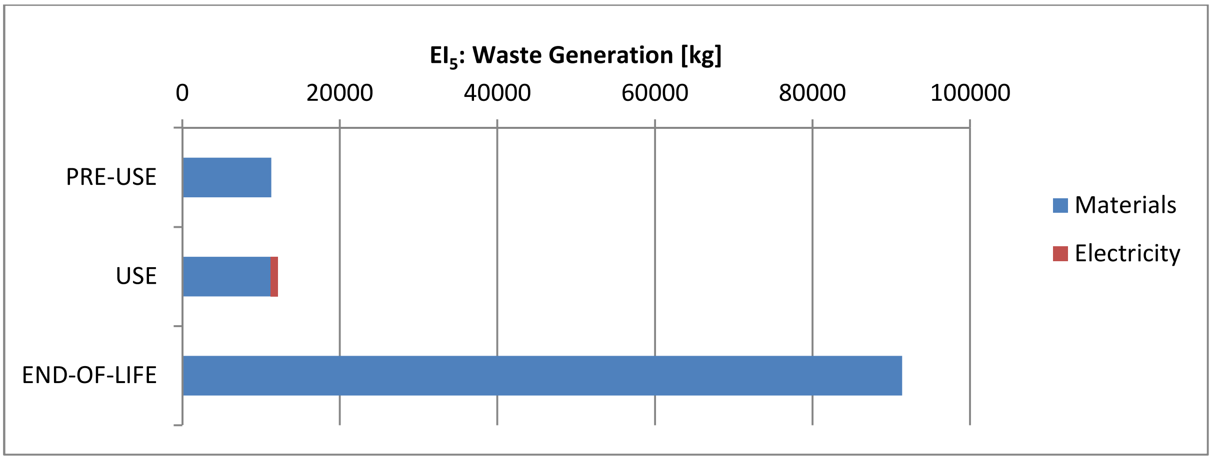


FIGURE C-16: WASTE GENERATION (EI5) OF REFERENCE BUILDING

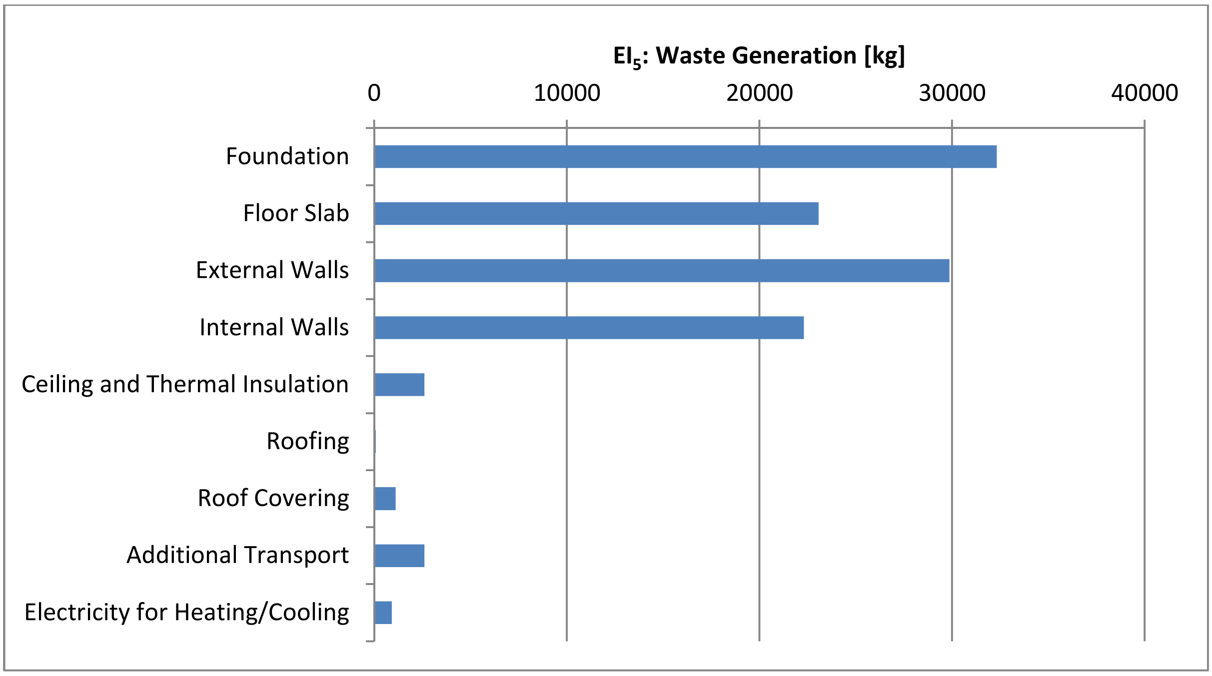


FIGURE C-17: WASTE GENERATION (EI5) OF REFERENCE BUILDING - ALL COMPONENTS, FULL LIFE CYCLE

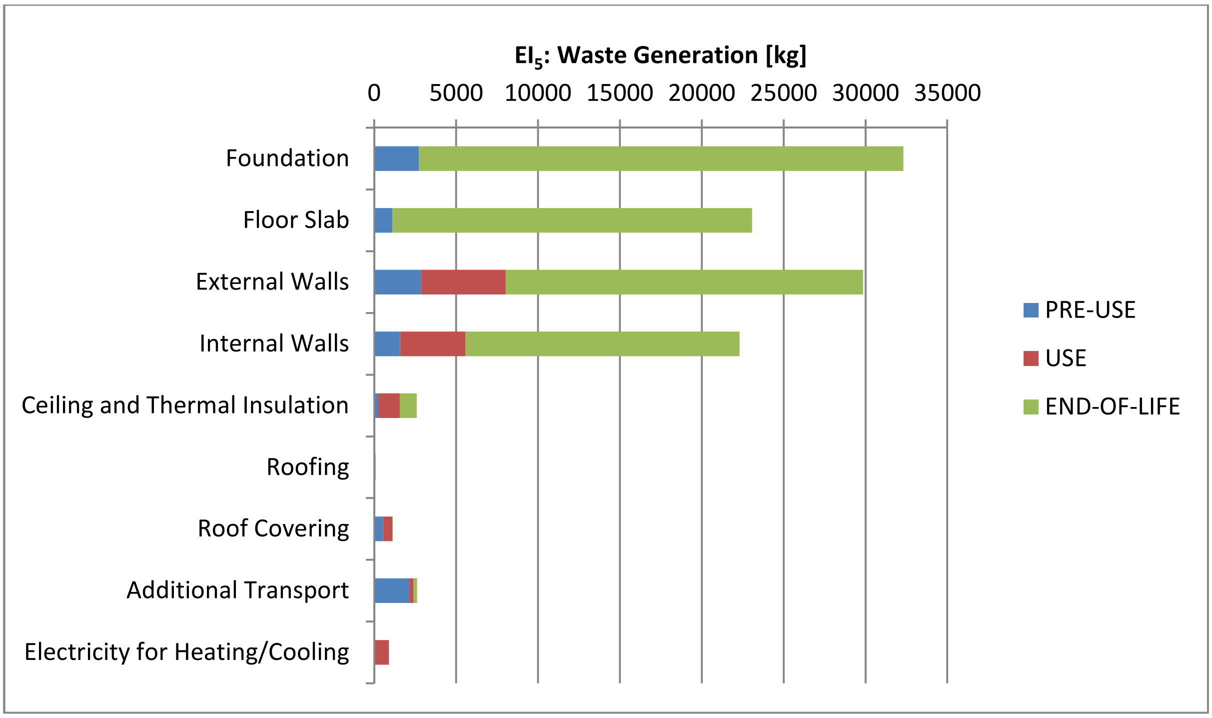


FIGURE C-18: WASTE GENERATION (EI5) OF REFERENCE BUILDING - ALL COMPONENTS, PER PHASE

Appendix D: COMPLETE LCA RESULTS

D1. External Walling System 01: Reference Design (Single leaf hollow concrete masonry)

SANS 10400-XA House: 01 REFERENCE DESIGN

																	EI$_5$: Waste Generation			
Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO$_{2e}$/unit]	[kg CO$_{2e}$/item]	[kg SO$_{2e}$/unit]	[kg SO$_{2e}$/item]	[kg NO$_3^-$/unit]	[kg NO$_3^-$/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 140 mm																				
Two top courses of brickwork to be filled with 10 Mpa concrete	concrete production, normal	RoW	m^3	1.02	2454.11	m^3	1.00	1.02	370.4100	378.76	1.0317	1.05	2.4093	2.46	2478.2760	2534.15	36.7870	37.62	0.03	73.62
Blockwork, mortar (140mm)	concrete block production	RoW	m^2	89.80	14367.75	kg	160.00 [1]	14367.75	0.1807	2596.54	0.0006	8.62	0.0018	25.47	1.4632	21022.41	0.0278	399.01	1.96	2157.32
brickforce as NHBRC standard	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	2.6463	69.20	0.0120	0.31	0.0677	1.77	39.2618	1026.62	0.9042	23.64	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	4.70		m^2	1.00	4.70	5.3066	24.96	0.30194	1.42	0.56793	2.67	106.39365	500.48	0.28081	1.32	0.00	0.00
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	9259.74	92597.45	tkm	1.00	9259.74	0.53068	4913.96	0.0030851	28.57	0.0062793	58.14	8.694566	80509.46	0.22901	2120.57		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	64.78		tkm	1.00	64.78	0.53068	34.38	0.0030851	0.20	0.0062793	0.41	8.694566	563.22	0.22901	14.83		
Sub-Totals																		4821.09		6477.87
PRE-USE PHASE IMPACT										25416.71		134.87		347.12		272227.30				11298.96

SANS 10400-XA House: 01 REFERENCE DESIGN

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 140 mm																				
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
										0.00		0.00		0.00		0.00		0.00		
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1038.03	10380.25	tkm	1.00	1038.03	0.53068	550.86	0.0030851	3.20	0.0062793	6.52	8.694566	9025.18	0.22901	237.72		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	4.41		tkm	1.00	4.41	0.53068	2.34	0.0030851	0.01	0.0062793	0.03	8.694566	38.30	0.22901	1.01		
DISPOSAL OF OLD PARTS																				
External walls 140 mm																				
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	105.79	10579.14	tkm	1.00	105.79	0.53068	56.14	0.0030851	0.33	0.0062793	0.66	8.694566	919.81	0.22901	24.23		
Sub-Totals: Materials										6608.99		75.34		156.86		87701.38		10814.92		440.53
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								6608.99		75.34		156.86		87701.38				11255.45
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	5881.14		kWh	1.00	5881.142275	1.1186	6578.65	0.011452	67.35	0.032065	188.58	15.4220204	90699.10	0.0051195	30.11		
Use Phase: Operation Impact	Design working life (years):	30								197359.37		2020.53		5657.36		2720972.88				903.26
USE PHASE IMPACT										203968.36		2095.86		5814.23		2808674.26				12158.70

SANS 10400-XA House: 01 REFERENCE DESIGN

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 140 mm																				
Two top courses of brickwork to be filled with 10 Mpa concrete	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	1.02	2454.11	kg	2400.00 [5]	2454.11	0.0129	31.64	0.0001	0.26	0.0002	0.50	0.3015	739.86	1.0022	2459.51		
Blockwork, mortar (140mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	89.80	14367.75	kg	160.00 [1]	14367.75	0.0129	185.21	0.0001	1.55	0.0002	2.92	0.3015	4331.56	1.0022	14399.36		
brickforce as NHBRC standard	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.73	0.0001	0.00		
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	925.97	92597.45	tkm	1.00	925.97	0.53068	491.40	0.0030851	2.86	0.0062793	5.81	8.694566	8050.95	0.22901	212.06		
Sub-Totals																		91389.70		
END-OF-LIFE PHASE IMPACT										1681.49		25.55		29.33		35527.08				91389.70
TOTAL LIFE CYCLE IMPACT										231066.56		2256.28		6190.67		3116428.64				114847.37

D2. External Walling System 02: Single Leaf Clay Masonry

SANS 10400-XA House: 02 SINGLE LEAF BRICK (140mm)

																	EI$_5$: Waste Generation			
Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 140 mm																				
Blockwork, brick (140mm)	brick production	RoW	m^3	12.57	28915.09	kg	2300.00 [10]	28915.09	0.2534	7327.66	0.0010	28.64	0.0018	50.99	3.3842	97854.46	0.0093	269.58	1.96	4510.75
brickforce as NHBRC standard	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	2.6463	69.20	0.0120	0.31	0.0677	1.77	39.2618	1026.62	0.9042	23.64	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	4.70		m^2	1.00	4.70	5.3066	24.96	0.30194	1.42	0.56793	2.67	106.39365	500.48	0.28081	1.32	0.00	0.00
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	10469.07	104690.68	tkm	1.00	10469.07	0.53068	5555.73	0.0030851	32.30	0.0062793	65.74	8.694566	91024.01	0.22901	2397.52		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	87.58		tkm	1.00	87.58	0.53068	46.48	0.0030851	0.27	0.0062793	0.55	8.694566	761.44	0.22901	20.06		
Sub-Totals																		4936.22		8757.68
PRE-USE PHASE IMPACT										30422.93		157.64		377.91		357237.96				13693.90

SANS 10400-XA House: 02 SINGLE LEAF BRICK (140mm)

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 140 mm																				
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1038.03	10380.25	tkm	1.00	1038.03	0.53068	550.86	0.0030851	3.20	0.0062793	6.52	8.694566	9025.18	0.22901	237.72		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	4.41		tkm	1.00	4.41	0.53068	2.34	0.0030851	0.01	0.0062793	0.03	8.694566	38.30	0.22901	1.01		
DISPOSAL OF OLD PARTS																				
External walls 140 mm																				
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	105.79	10579.14	tkm	1.00	105.79	0.53068	56.14	0.0030851	0.33	0.0062793	0.66	8.694566	919.81	0.22901	24.23		
Sub-Totals: Materials										6608.99		75.34		156.86		87701.38		10814.92		440.53
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								6608.99		75.34		156.86		87701.38				11255.45
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	5282.41		kWh	1.00	5282.414839	1.1186	5908.91	0.011452	60.49	0.032065	169.38	15.4220204	81465.51	0.0051195	27.04		
Use Phase: Operation Impact	Design working life (years):	30								177267.28		1814.83		5081.42		2443965.28				811.30
USE PHASE IMPACT										183876.26		1890.16		5238.28		2531666.66				12066.75

SANS 10400-XA House: 02 SINGLE LEAF BRICK (140mm)

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 140 mm																				
Blockwork, brick (140mm)	treatment of waste brick, collection for final disposal	CH	m^3	12.57	28915.09	kg	2300.00 [10]	28915.09	0.0121	351.26	0.0001	2.92	0.0002	5.51	0.2898	8381.03	1.0022	28978.71		
brickforce as NHBRC standard	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.73	0.0001	0.00		
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1046.91	104690.68	tkm	1.00	1046.91	0.53068	555.57	0.0030851	3.23	0.0062793	6.57	8.694566	9102.40	0.22901	239.75		
Sub-Totals																		103537.24		
END-OF-LIFE PHASE IMPACT										1880.08		27.02		32.18		39888.15				103537.24
TOTAL LIFE CYCLE IMPACT										216179.28		2074.83		5648.37		2928792.77				129297.88

D3. External Walling System 03: Double Leaf Brick Cavity Wall

SANS 10400-XA House: 03 DOUBLE LEAF BRICK (2x90mm)

Materials						Conversion			EI1: Carbon Footprint		EI2: Acidification Potential		EI3: Eutrophication Potential		EI4: Resource Depletion		EI5: Waste Generation – Waste from Production		EI5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 2 x 90 mm																				
Blockwork, brick (2x90mm)	brick production	RoW	m^3	16.16	37176.55	kg	2300.00 [10]	37176.55	0.2534	9421.28	0.0010	36.82	0.0018	65.56	3.3842	125812.87	0.0093	346.60	2.52	5799.54
brickforce as NHBRC standard	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	2.6463	69.20	0.0120	0.31	0.0677	1.77	39.2618	1026.62	0.9042	23.64	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	4.70		m^2	1.00	4.70	5.3066	24.96	0.30194	1.42	0.56793	2.67	106.39365	500.48	0.28081	1.32	0.00	0.00
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	11295.21	112952.14	tkm	1.00	11295.21	0.53068	5994.14	0.0030851	34.85	0.0062793	70.93	8.694566	98206.98	0.22901	2586.72		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	100.46		tkm	1.00	100.46	0.53068	53.31	0.0030851	0.31	0.0062793	0.63	8.694566	873.50	0.22901	23.01		
Sub-Totals																		5205.38		10046.47
PRE-USE PHASE IMPACT										32961.81		168.41		397.74		392491.40				15251.85

SANS 10400-XA House: 03 DOUBLE LEAF BRICK (2x90mm)

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 2 x 90 mm																				
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	[5] 27.60	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	[5] 27.60	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	[5] 27.60	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	[6] 5.70	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	[7] 5.80	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	[8] 5.03	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	[8] 2.26	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1038.03	10380.25	tkm	1.00	1038.03	0.53068	550.86	0.0030851	3.20	0.0062793	6.52	8.694566	9025.18	0.22901	237.72		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	4.41		tkm	1.00	4.41	0.53068	2.34	0.0030851	0.01	0.0062793	0.03	8.694566	38.30	0.22901	1.01		
DISPOSAL OF OLD PARTS																				
External walls 2 x 90 mm																				
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	[5] 27.60	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	[5] 27.60	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	[5] 27.60	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	[6] 5.70	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	[7] 5.80	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	[8] 5.03	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	[8] 2.26	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	105.79	10579.14	tkm	1.00	105.79	0.53068	56.14	0.0030851	0.33	0.0062793	0.66	8.694566	919.81	0.22901	24.23		
Sub-Totals: Materials										6608.99		75.34		156.86		87701.38		10814.92		440.53
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								6608.99		75.34		156.86		87701.38				11255.45
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	4371.43		kWh	1.00	4371.42778	1.1186	4889.88	0.011452	50.06	0.032065	140.17	15.4220204	67416.25	0.0051195	22.38		
Use Phase: Operation Impact	Design working life (years):	30								146696.37		1501.85		4205.09		2022487.45				671.39
USE PHASE IMPACT										153305.36		1577.18		4361.96		2110188.83				11926.83

SANS 10400-XA House: 03 DOUBLE LEAF BRICK (2x90mm)

Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		EI$_5$: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 2 x 90 mm																				
Blockwork, brick (140mm)	treatment of waste brick, collection for final disposal	CH	m^3	16.16	37176.55	kg	2300.00 [10]	37176.55	0.0121	451.62	0.0001	3.75	0.0002	7.09	0.2898	10775.61	1.0022	37258.34		
brickforce as NHBRC standard	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	240.00	26.15	kg	0.11 [2]	26.15	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.73	0.0001	0.00		
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1129.52	112952.14	tkm	1.00	1129.52	0.53068	599.41	0.0030851	3.48	0.0062793	7.09	8.694566	9820.70	0.22901	258.67		
Sub-Totals																		111835.79		
END-OF-LIFE PHASE IMPACT										2024.28		28.11		34.27		43001.03				111835.79
TOTAL LIFE CYCLE IMPACT										188291.45		1773.71		4793.97		2545681.26				139014.48

D4. External Walling System 04: Cast Concrete Wall

SANS 10400-XA House: 04 CAST CONCRETE (200mm)

Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		EI$_5$: Waste Generation – Waste from Production		EI$_5$: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 200 mm																				
Cast concrete (200mm)	concrete production, normal	RoW	m^3	17.96	43103.24	m^3	1.00	17.96	370.4100	6652.45	1.0317	18.53	2.4093	43.27	2478.2760	44509.06	36.7870	660.68	0.54	1293.10
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	11885.27	118852.69	tkm	1.00	11885.27	0.53068	6307.27	0.0030851	36.67	0.0062793	74.63	8.694566	103337.25	0.22901	2721.85		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	55.40		tkm	1.00	55.40	0.53068	29.40	0.0030851	0.17	0.0062793	0.35	8.694566	481.68	0.22901	12.69		
Sub-Totals																		5619.31		5540.02
PRE-USE PHASE IMPACT										30388.03		150.07		374.43		314398.95				11159.33

SANS 10400-XA House: 04 CAST CONCRETE (200mm)

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 200 mm																				
Plaster externally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Plaster internally (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.2631	652.02	0.0007	1.83	0.0016	3.85	1.5682	3886.71	0.0072	17.72	0.03	74.35
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1038.03	10380.25	tkm	1.00	1038.03	0.53068	550.86	0.0030851	3.20	0.0062793	6.52	8.694566	9025.18	0.22901	237.72		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	4.41		tkm	1.00	4.41	0.53068	2.34	0.0030851	0.01	0.0062793	0.03	8.694566	38.30	0.22901	1.01		
DISPOSAL OF OLD PARTS																				
External walls 200 mm																				
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	105.79	10579.14	tkm	1.00	105.79	0.53068	56.14	0.0030851	0.33	0.0062793	0.66	8.694566	919.81	0.22901	24.23		
Sub-Totals: Materials										6608.99		75.34		156.86		87701.38		10814.92		440.53
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								6608.99		75.34		156.86		87701.38				11255.45
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	5402.20		kWh	1.00	5402.196774	1.1186	6042.90	0.011452	61.87	0.032065	173.22	15.4220204	83312.79	0.0051195	27.66		
Use Phase: Operation Impact	Design working life (years):	30								181286.92		1855.98		5196.64		2499383.67				829.70
USE PHASE IMPACT										187895.91		1931.31		5353.51		2587085.04				12085.14

SANS 10400-XA House: 04 CAST CONCRETE (200mm)

																	EI_5: Waste Generation			
Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 200 mm																				
Cast concrete (200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	17.96	43103.24	kg	2400.00 [5]	43103.24	0.0129	555.64	0.0001	4.65	0.0002	8.76	0.3015	12994.68	1.0022	43198.07		
Plaster externally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
Plaster internally (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	89.80	2478.44	kg	27.60 [5]	2478.44	0.0087	21.63	0.0001	0.17	0.0001	0.33	0.2363	585.75	1.0022	2483.89		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1188.53	118852.69	tkm	1.00	1188.53	0.53068	630.73	0.0030851	3.67	0.0062793	7.46	8.694566	10333.73	0.22901	272.18		
Sub-Totals																		117789.04		
END-OF-LIFE PHASE IMPACT										2159.57		29.19		36.32		45732.38				117789.04
TOTAL LIFE CYCLE IMPACT										220443.51		2110.58		5764.26		2947216.37				141033.51

D5. External Walling System 05: Innovida Building System

SANS 10400-XA House: 05 Innovida Building System

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 70mm																				
Expanded polyurethane core (60mm)	polyurethane production, rigid foam	RoW	m^3	5.39	12930.97	kg	24.00 [11]	129.31	4.4227	571.90	0.0195	2.53	0.0381	4.93	106.2237	13735.75	0.2054	26.56	0.05	1.29
Resin-saturated glass fibre sheet (2x2mm)	glass fibre production	RoW	m^3	0.36	8.62	kg	24.00 [12]	8.62	2.4894	21.46	0.0213	0.18	0.0377	0.32	39.6574	341.87	0.2325	2.00	0.00	0.09
Glass fibre base rail (70x60x2)	glass fibre production	RoW	m^3	0.02	0.36	kg	24.00 [12]	0.36	2.4894	0.91	0.0213	0.01	0.0377	0.01	39.6574	14.47	0.2325	0.08	0.00	0.00
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	8373.25	83732.53	tkm	1.00	8373.25	0.53068	4443.52	0.0030851	25.83	0.0062793	52.58	8.694566	72801.80	0.22901	1917.56		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	41.00		tkm	1.00	41.00	0.53068	21.76	0.0030851	0.13	0.0062793	0.26	8.694566	356.44	0.22901	9.39		
Sub-Totals																		4144.25		4099.60
PRE-USE PHASE IMPACT										21154.42		119.71		306.59		245547.87				8243.85

SANS 10400-XA House: 05 Innovida Building System

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 70mm																				
Resin-saturated glass fibre sheet (2x2mm)	glass fibre production	RoW	m^3	0.36	8.62	kg	24.00 [12]	8.62	0.2631	2.27	0.0007	0.01	0.0016	0.01	1.5682	13.52	0.0072	0.06	0.00	0.09
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	543.20	5432.00	tkm	1.00	543.20	0.53068	288.27	0.0030851	1.68	0.0062793	3.41	8.694566	4722.89	0.22901	124.40		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	2.92		tkm	1.00	2.92	0.53068	1.55	0.0030851	0.01	0.0062793	0.02	8.694566	25.38	0.22901	0.67		
DISPOSAL OF OLD PARTS																				
External walls 70mm																				
Resin-saturated glass fibre sheet (2x2mm)	treatment of waste glass, inert material landfill	CH	m^3	0.36	8.62	kg	24.00 [12]	8.62	0.0055	0.05	0.0000	0.00	0.0001	0.00	0.1829	1.58	0.9997	8.62		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	56.31	5630.89	tkm	1.00	56.31	0.53068	29.88	0.0030851	0.17	0.0062793	0.35	8.694566	489.58	0.22901	12.90		
Sub-Totals: Materials										4974.38		69.65		145.10		74026.10		5695.38		291.91
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								4974.38		69.65		145.10		74026.10				5987.29
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	3700.85		kWh	1.00	3700.849669	1.1186	4139.77	0.011452	42.38	0.032065	118.67	15.4220204	57074.58	0.0051195	18.95		
Use Phase: Operation Impact	Design working life (years):	30								124193.11		1271.46		3560.03		1712237.37				568.39
USE PHASE IMPACT										129167.49		1341.11		3705.13		1786263.48				6555.69

SANS 10400-XA House: 05 Innovida Building System

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 70mm																				
Expanded polyurethane core (60mm)	treatment of waste polyurethane, sanitary landfill	RoW	m^3	5.39	12930.97	kg	24.00 [11]	129.31	0.0910	11.77	0.0001	0.02	0.1915	24.76	0.3967	51.30	1.0025	129.63		
Resin-saturated glass fibre sheet (2x2mm)	treatment of waste glass, inert material landfill	CH	m^3	0.36	8.62	kg	24.00 [12]	8.62	0.0055	0.05	0.0000	0.00	0.0001	0.00	0.1829	1.58	0.9997	8.62		
Glass fibre base rail (70x60x2)	treatment of waste glass, inert material landfill	CH	m^3	0.02	0.36	kg	24.00 [12]	0.36	0.0055	0.00	0.0000	0.00	0.0001	0.00	0.1829	0.07	0.9997	0.36		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	837.33	83732.53	tkm	1.00	837.33	0.53068	444.35	0.0030851	2.58	0.0062793	5.26	8.694566	7280.18	0.22901	191.76		
Sub-Totals																		69681.37		
END-OF-LIFE PHASE IMPACT										1386.12		23.14		49.46		28565.60				69681.37
TOTAL LIFE CYCLE IMPACT										151708.03		1483.96		4061.18		2060376.95				84480.91

D6. External Walling System 06: Affordable Comfort Homes

SANS 10400-XA House: 06 Affordable Comfort Homes

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls 60mm																				
Expanded polyurethane core (60mm)	polyurethane production, rigid foam	RoW	m^3	5.39	12930.97	kg	24.00 [11]	129.31	4.4227	571.90	0.0195	2.53	0.0381	4.93	106.2237	13735.75	0.2054	26.56	0.05	1.29
Gypsum plaster board (15mm)	gypsum plasterboard production	RoW	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.3901	472.92	0.0026	3.15	0.0065	7.85	5.1088	6193.33	0.0239	28.95	0.34	303.07
Sheet steel (2x0.6mm)	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^3	0.11	840.51	kg	7800.00 [14]	840.51	2.5994	2184.82	0.0127	10.63	0.0681	57.28	39.9104	33545.19	0.8821	741.44	0.01	76.49
galvanised	zinc coating, coils	RoW	m^2	179.60		m^2	1.00	179.60	5.3066	953.05	0.30194	54.23	0.56793	102.00	106.39365	19107.96	0.28081	50.43	0.00	0.00
Steel fibre base rail (52x52x2)	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^3	0.01	97.34	kg	7800.00 [14]	97.34	2.5994	253.04	0.0127	1.23	0.0681	6.63	39.9104	3885.03	0.8821	85.87	0.00	8.86
galvanised	zinc coating, coils	RoW	m^2	12.48		m^2	1.00	12.48	5.3066	66.23	0.30194	3.77	0.56793	7.09	106.39365	1327.79	0.28081	3.50	0.00	0.00
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	8587.37	85873.68	tkm	1.00	8587.37	0.53068	4557.14	0.0030851	26.49	0.0062793	53.92	8.694566	74663.44	0.22901	1966.59		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	44.88		tkm	1.00	44.88	0.53068	23.82	0.0030851	0.14	0.0062793	0.28	8.694566	390.21	0.22901	10.28		
Sub-Totals																		5102.28		4487.93
PRE-USE PHASE IMPACT										25177.79		193.20		488.47		311146.23				9590.21

SANS 10400-XA House: 06 Affordable Comfort Homes

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls 60mm																				
Gypsum plaster board (15mm)	gypsum plasterboard production	RoW	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.3901	472.92	0.0026	3.15	0.0065	7.85	5.1088	6193.33	0.0239	28.95	0.34	303.07
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	663.57	6635.66	tkm	1.00	663.57	0.53068	352.14	0.0030851	2.05	0.0062793	4.17	8.694566	5769.42	0.22901	151.96		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	5.95		tkm	1.00	5.95	0.53068	3.16	0.0030851	0.02	0.0062793	0.04	8.694566	51.72	0.22901	1.36		
DISPOSAL OF OLD PARTS																				
External walls 60mm																				
Gypsum plaster board (15mm)	treatment of waste gypsum, sanitary landfill	CH	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.0122	14.81	0.0249	30.21	0.0002	0.29	0.3342	405.19	1.0037	1216.76		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	68.35	6834.55	tkm	1.00	68.35	0.53068	36.27	0.0030851	0.21	0.0062793	0.43	8.694566	594.23	0.22901	15.65		
Sub-Totals: Materials										5531.67		103.42		154.07		81787.05		6963.43		594.90
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								5531.67		103.42		154.07		81787.05				7558.33
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	3634.86		kWh	1.00	3634.863247	1.1186	4065.96	0.011452	41.63	0.032065	116.55	15.4220204	56056.94	0.0051195	18.61		
Use Phase: Operation Impact	Design working life (years):	30								121978.74		1248.79		3496.56		1681708.05				558.26
USE PHASE IMPACT										127510.41		1352.22		3650.63		1763495.11				8116.59

SANS 10400-XA House: 06 Affordable Comfort Homes

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
Floor Slab																				
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
External walls 60mm																				
Expanded polyurethane core (60mm)	treatment of waste polyurethane, sanitary landfill	RoW	m^3	5.39	12930.97	kg	24.00 [11]	129.31	0.0910	11.77	0.0001	0.02	0.1915	24.76	0.3967	51.30	1.0025	129.63		
Gypsum plaster board (15mm)	treatment of waste gypsum, sanitary landfill	CH	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.0122	14.81	0.0249	30.21	0.0002	0.29	0.3342	405.19	1.0037	1216.76		
Sheet steel (2x0.6mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^3	0.11	840.51	kg	7800.00 [14]	840.51	0.0018	1.55	0.0000	0.01	0.0000	0.04	0.0281	23.58	0.0001	0.04		
Steel fibre base rail (52x52x2)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^3	0.01	97.34	kg	7800.00 [14]	97.34	0.0018	0.18	0.0000	0.00	0.0000	0.00	0.0281	2.73	0.0001	0.01		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	858.74	85873.68	tkm	1.00	858.74	0.53068	455.71	0.0030851	2.65	0.0062793	5.39	8.694566	7466.34	0.22901	196.66		
Sub-Totals																		70894.11		
END-OF-LIFE PHASE IMPACT										1413.97		53.43		49.92		29181.63				70894.11
TOTAL LIFE CYCLE IMPACT										154102.17		1598.85		4189.01		2103822.97				88600.91

D7. External Walling System 07: MG Sip Building System

SANS 10400-XA House: 07 MG SIP BUILDING SYSTEM																	EI$_5$: Waste Generation			
Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls (125mm)																				
Expanded polyurethane core (103mm)	polyurethane production, rigid foam	RoW	m^3	9.25	22198.17	kg	24.00 [11]	221.98	4.4227	981.76	0.0195	4.34	0.0381	8.46	106.2237	23579.71	0.2054	45.60	0.09	2.22
Gypsum plaster board (15mm)	gypsum plasterboard production	RoW	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.3901	472.92	0.0026	3.15	0.0065	7.85	5.1088	6193.33	0.0239	28.95	0.34	303.07
Oriented strand board (2x11mm)	oriented strand board production	RoW	m^3	1.98	1284.12	m^3	1.00	1.98	320.2200	632.62	2.1864	4.32	10.5680	20.88	6222.8060	12293.56	58.3870	115.35	0.49	0.49
Medium density fibre-cement board (12mm)	fibre cement corrugated slab production	RoW	m^3	1.08	862.06	kg	800.00 [15]	862.06	0.87978	758.43	0.0036862	3.18	0.012179	10.50	9.23963	7965.16	0.064818	55.88	0.27	215.52
Steel fibre base rail (127x52x2)	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^3	0.02	144.14	kg	7800.00 [14]	144.14	320.2200	46157.79	2.1864	315.16	10.5680	1523.31	6222.8060	896980.15	58.3870	8416.14	0.00	13.12
galvanised	zinc coating, coils	RoW	m^2	18.48		m^2	1.00	18.48	0.87978	16.26	0.0036862	0.07	0.012179	0.23	9.23963	170.75	0.064818	1.20	0.00	0.00
Brandering (38x38mm @300mm)	planing, beam, softwood, air dried	RoW	m^3	1.04	519.84	m^3	1.00	1.04	105.2800	109.46	0.6861	0.71	5.8563	6.09	1666.1729	1732.29	39.9590	41.54	0.00	0.00
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.00	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	9701.32	97013.19	tkm	1.00	9701.32	0.53068	5148.30	0.0030851	29.93	0.0062793	60.92	8.694566	84348.75	0.22901	2221.70		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	46.33		tkm	1.00	46.33	0.53068	24.58	0.0030851	0.14	0.0062793	0.29	8.694566	402.79	0.22901	10.61		
Sub-Totals																		13125.61		4632.64
PRE-USE PHASE IMPACT										70396.99		452.03		1887.01		1191964.01				17758.24

SANS 10400-XA House: 07 MG SIP BUILDING SYSTEM

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls (125mm)																				
Gypsum plaster board (15mm)	gypsum plasterboard production	RoW	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.3901	472.92	0.0026	3.15	0.0065	7.85	5.1088	6193.33	0.0239	28.95	0.34	303.07
Medium density fibre-cement board (12mm)	fibre cement corrugated slab production	RoW	m^3	1.08	862.06	kg	800.00 [15]	862.06	0.87978	758.43	0.0036862	3.18	0.012179	10.50	9.23963	7965.16	0.064818	55.88	0.00	0.00
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
										0.00		0.00		0.00		0.00		0.00		
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	749.77	7497.72	tkm	1.00	749.77	0.53068	397.89	0.0030851	2.31	0.0062793	4.71	8.694566	6518.94	0.22901	171.71		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	5.95		tkm	1.00	5.95	0.53068	3.16	0.0030851	0.02	0.0062793	0.04	8.694566	51.72	0.22901	1.36		
DISPOSAL OF OLD PARTS																				
External walls (125mm)																				
Gypsum plaster board (15mm)	treatment of waste gypsum, sanitary landfill	CH	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.0122	14.81	0.0249	30.21	0.0002	0.29	0.3342	405.19	1.0037	1216.76		
Medium density fibre-cement board (12mm)	treatment of waste fibreboard, collection for final disposal	RoW	m^3	1.08	862.06	kg	800.00 [15]	862.06	0.0961	82.88	0.0005	0.44	0.0063	5.46	0.3406	293.61	0.0648	55.85		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	76.97	7696.61	tkm	1.00	76.97	0.53068	40.84	0.0030851	0.24	0.0062793	0.48	8.694566	669.19	0.22901	17.63		
Sub-Totals: Materials										6423.29		107.33		170.62		90870.31		7096.88		594.90
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								6423.29		107.33		170.62		90870.31				7691.78
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	3327.65		kWh	1.00	3327.654968	1.1186	3722.31	0.011452	38.11	0.032065	106.70	15.4220204	51319.16	0.0051195	17.04		
Use Phase: Operation Impact	Design working life (years):	30								111669.45		1143.25		3201.04		1539574.88				511.08
USE PHASE IMPACT										118092.74		1250.58		3371.66		1630445.19				8202.85

SANS 10400-XA House: 07 MG SIP BUILDING SYSTEM

																	EI5: Waste Generation			
Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
										0.00		0.00		0.00		0.00		0.00		
Floor Slab										0.00		0.00		0.00		0.00		0.00		
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
										0.00		0.00		0.00		0.00		0.00		
External walls (125mm)										0.00		0.00		0.00		0.00		0.00		
Expanded polyurethane core (103mm)	treatment of waste polyurethane, sanitary landfill	RoW	m^3	9.25	22198.17	kg	24.00 [11]	221.98	0.0910	20.21	0.0001	0.03	0.1915	42.51	0.3967	88.06	1.0025	222.54		
Gypsum plaster board (15mm)	treatment of waste gypsum, sanitary landfill	CH	m^3	1.35	1212.28	kg	900.00 [13]	1212.28	0.0122	14.81	0.0249	30.21	0.0002	0.29	0.3342	405.19	1.0037	1216.76		
Oriented strand board (2x11mm)	treatment of waste fibreboard, collection for final disposal	RoW	m^3	1.98	1284.12	kg	650.00 [16]	1284.12	0.0961	123.45	0.0005	0.65	0.0063	8.13	0.3406	437.36	0.0648	83.20		
Medium density fibre-cement board (12mm)	treatment of waste fibreboard, collection for final disposal	RoW	m^3	1.08	862.06	kg	800.00 [15]	862.06	0.0961	82.88	0.0005	0.44	0.0063	5.46	0.3406	293.61	0.0648	55.85		
Steel fibre base rail (127x52x2)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^3	0.02	144.14	kg	7800.00 [14]	144.14	0.0961	13.86	0.0005	0.07	0.0063	0.91	0.3406	49.09	0.0648	9.34		
Brandering (38x38mm @300mm)	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.04	519.84	kg	500.00 [9]	519.84	0.0146	7.59	0.0002	0.08	0.0006	0.30	0.1663	86.46	0.0120	6.22		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation										0.00		0.00		0.00		0.00		0.00		
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	970.13	97013.19	tkm	1.00	970.13	0.53068	514.83	0.0030851	2.99	0.0062793	6.09	8.694566	8434.88	0.22901	222.17		
Sub-Totals																		71167.08		
END-OF-LIFE PHASE IMPACT										1707.57		55.02		83.13		31027.13				71167.08
TOTAL LIFE CYCLE IMPACT										190197.30		1757.63		5341.80		2853436.33				97128.18

D8. External Walling System 08: Blast Building System

SANS 10400-XA House: 08 BLAST BUILDING SYSTEM

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls (90mm)																				
Sprayed concrete (90mm)	concrete production, normal	RoW	m^3	8.08	19396.46	m^3	1.00	8.08	370.4100	2993.60	1.0317	8.34	2.4093	19.47	2478.2760	20029.08	36.7870	297.31	0.27	581.89
Weldmesh (50x50x2.5mm)	reinforcing steel production; section bar rolling, steel	RoW	m^2	89.80	57.20	kg	1.57 [17]	57.20	2.6337	150.64	0.0107	0.61	0.0495	2.83	34.5065	1973.65	0.6712	38.39	0.00	2.86
Plaster, external (15mm)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	179.60	6196.09	kg	34.50 [5]	6196.09	0.2631	1630.04	0.0007	4.59	0.0016	9.62	1.5682	9716.79	0.0072	44.30	0.00	185.88
Magboard, internal (6mm)	magnesium oxide production	RoW	m^3	0.54	538.79	kg	1000.00 [18]	538.79	1.1278	607.65	0.0022	1.19	0.0047	2.53	5.4420	2932.10	0.0050	2.67	0.00	134.70
Zincalume base rail & top channel (90x40x1.5mm)	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^3	0.01	79.56	kg	7800.00 [14]	79.56	2.5994	206.81	0.0127	1.01	0.0681	5.42	39.9104	3175.27	0.8821	70.18	0.24	7.24
galvanised	zinc coating, coils	RoW	m^2	13.60		m^2	1.00	13.60	5.3066	72.17	0.30194	4.11	0.56793	7.72	106.39365	1446.95	0.28081	3.82	0.00	0.00
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.08	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	9706.07	97060.67	tkm	1.00	9706.07	0.53068	5150.82	0.0030851	29.94	0.0062793	60.95	8.694566	84390.04	0.22901	2222.79		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	50.11		tkm	1.00	50.11	0.53068	26.59	0.0030851	0.15	0.0062793	0.31	8.694566	435.67	0.22901	11.48		
Sub-Totals																		4879.59		5010.79
PRE-USE PHASE IMPACT										26933.19		140.97		357.35		282397.06				9890.38

SANS 10400-XA House: 08 BLAST BUILDING SYSTEM

																	EI$_5$: Waste Generation			
Materials						Conversion			EI$_1$: Carbon Footprint		EI$_2$: Acidification Potential		EI$_3$: Eutrophication Potential		EI$_4$: Resource Depletion		Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls (90mm)																				
Plaster, external (15mm)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	179.60	6196.09	kg	[5] 34.50	6196.09	0.26	1630.04	0.00	4.59	0.00	9.62	1.57	9716.79	0.01	44.30	0.08	185.88
Magboard, internal (6mm)	magnesium oxide production	RoW	m^3	0.54	538.79	kg	[18] 1000.00	538.79	1.13	607.65	0.00	1.19	0.00	2.53	5.44	2932.10	0.00	2.67	0.13	134.70
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	[5] 27.60	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	[6] 5.70	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	[7] 5.80	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	[8] 5.03	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	[8] 2.26	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	1215.83	12158.26	tkm	1.00	1215.83	0.53068	645.21	0.0030851	3.75	0.0062793	7.63	8.694566	10571.08	0.22901	278.44		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	6.12		tkm	1.00	6.12	0.53068	3.25	0.0030851	0.02	0.0062793	0.04	8.694566	53.25	0.22901	1.40		
DISPOSAL OF OLD PARTS																				
External walls (90mm)																				
Plaster, external (15mm)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	179.60	6196.09	kg	[5] 34.50	6196.09	0.0087	54.06	0.0001	0.43	0.0001	0.82	0.2363	1464.37	1.0022	6209.72		
Magboard, internal (6mm)	treatment of waste fibreboard, collection for final disposal	RoW	m^3	0.54	538.79	kg	[18] 1000.00	538.79	0.0961	51.80	0.0005	0.27	0.0063	3.41	0.3406	183.51	0.0648	34.91		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	[5] 27.60	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	[6] 5.70	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	[7] 5.80	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	[8] 5.03	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	[8] 2.26	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	123.57	12357.15	tkm	1.00	123.57	0.53068	65.58	0.0030851	0.38	0.0062793	0.78	8.694566	1074.40	0.22901	28.30		
Sub-Totals: Materials										7709.96		78.41		166.13		94768.64		12148.48		612.41
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								7709.96		78.41		166.13		94768.64				12760.89
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	6746.44		kWh	1.00	6746.438773	1.1186	7546.57	0.011452	77.26	0.032065	216.32	15.4220204	104043.72	0.0051195	34.54		
Use Phase: Operation Impact	Design working life (years):	30								226396.99		2317.81		6489.74		3121311.49				1036.15
USE PHASE IMPACT										234106.95		2396.22		6655.87		3216080.14				13797.04

SANS 10400-XA House: 08 BLAST BUILDING SYSTEM

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
										0.00		0.00		0.00		0.00		0.00		
Floor Slab										0.00		0.00		0.00		0.00		0.00		
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
										0.00		0.00		0.00		0.00		0.00		
External walls (90mm)																				
Sprayed concrete (90mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	8.08	19396.46	kg	2400.00 [5]	19396.46	0.0129	250.04	0.0001	2.09	0.0002	3.94	0.3015	5847.60	1.0022	19439.13		
Weldmesh (50x50x2.5mm)	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	89.80	57.20	kg	1.57 [17]	57.20	0.1512	8.65	0.0010	0.06	0.0208	1.19	2.1420	122.51	0.2136	12.21		
Plaster, external (15mm)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	179.60	6196.09	kg	34.50 [5]	6196.09	0.0087	54.06	0.0001	0.43	0.0001	0.82	0.2363	1464.37	1.0022	6209.72		
Magboard, internal (6mm)	treatment of waste fibreboard, collection for final disposal	RoW	m^3	0.54	538.79	kg	1000.00 [18]	538.79	0.0961	51.80	0.0005	0.27	0.0063	3.41	0.3406	183.51	0.0648	34.91		
Zincalume base rail & top channel (90x40x1.5mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^3	0.01	79.56	kg	7800.00 [14]	79.56	0.0018	0.15	0.0000	0.00	0.0000	0.00	0.0281	2.23	0.0001	0.00		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation										0.00		0.00		0.00		0.00		0.00		
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	970.61	97060.67	tkm	1.00	970.61	0.53068	515.08	0.0030851	2.99	0.0062793	6.09	8.694566	8439.00	0.22901	222.28		
Sub-Totals																		95269.26		
END-OF-LIFE PHASE IMPACT										1809.72		26.38		34.90		37291.72				95269.26
TOTAL LIFE CYCLE IMPACT										262849.86		2563.56		7048.12		3535768.92				118956.68

D9. External Walling System 09: Ikhaya Future House Building System

SANS 10400-XA House: 09 Ikhaya Future House

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation			
																	Waste from Production		Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
PRE-USE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	concrete production, normal	RoW	m^3	7.32	17568.00	m^3	1.00	7.32	370.4100	2711.40	1.0317	7.55	2.4093	17.64	2478.2760	18140.98	36.7870	269.28	0.22	527.04
Reinforcing (4 x Y12)	reinforcing steel production; section bar rolling, steel	RoW	kg	68.95	68.95	kg	1.00	68.95	2.6337	181.61	0.0107	0.74	0.0494903	3.41	34.5065	2379.37	0.6712	46.28	0.00	3.45
190 mm solid blockwork (foundation wall)	concrete block production	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.1807	824.08	0.0006	2.73	0.0018	8.08	1.4632	6672.04	0.0278	126.64	0.35	384.38
400x210mm strip footing	concrete block production	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.1807	1335.88	0.0006	4.43	0.0018	13.11	1.4632	10815.73	0.0278	205.28	0.52	1153.15
brickforce (75x2.8mm)	steel production, low-alloyed, hot rolled; wire drawing, steel	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	2.6463	23.07	0.0120	0.10	0.0677	0.59	39.2618	342.21	0.9042	7.88	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	1.57		m^2	1.00	1.57	5.3066	8.32	0.30194	0.47	0.56793	0.89	106.39365	166.83	0.28081	0.44	0.00	0.00
Floor Slab																				
Damp proof membrane 250 micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	2.7305	57.15	0.0120	0.25	0.0277	0.58	83.9319	1756.70	0.0817	1.71	0.00	0.00
25 MPa concrete (power floated)	concrete production, normal	RoW	m^3	9.10	21840.00	m^3	1.00	9.10	370.4100	3370.73	1.0317	9.39	2.4093	21.92	2478.2760	22552.31	36.7870	334.76	0.27	655.20
steel mesh ref 193	reinforcing steel production; section bar rolling, steel	RoW	m^2	91.00	175.63	kg	1.93 [4]	175.63	2.6337	462.56	0.0107	1.88	0.0495	8.69	34.5065	6060.38	0.6712	117.89	0.00	8.78
External walls (160mm)																				
Expanded polystyrene core (80mm)	polystyrene production, expandable	RoW	m^3	7.18	17241.30	kg	16.00 [19]	114.94	3.3406	383.98	0.0105	1.21	0.0105	1.21	92.8484	10672.18	0.0648	7.45	0.27	28.74
Weldmesh, both sides (100x100x3.5mm)	reinforcing steel production; section bar rolling, steel	RoW	m^2	179.60	280.17	kg	1.56 [4]	280.17	2.6337	737.89	0.0107	2.99	0.0495	13.87	34.5065	9667.72	0.6712	188.06	0.00	14.01
Plaster, both sides (40mm)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	179.60	16522.91	kg	92.00 [5]	16522.91	0.2631	4346.77	0.0007	12.23	0.0016	25.66	1.5682	25911.43	0.0072	118.14	0.00	185.88
DPC - 375micron	polyethylene production, low density, granulate; extrusion production, plastic film	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	2.7305	4.14	0.0120	0.02	0.0277	0.04	83.9319	127.41	0.0817	0.12	0.08	0.00
Internal Walls 90 mm																				
Solid blockwork, mortar	concrete block production	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.1807	2325.84	0.0006	7.72	0.0018	22.82	1.4632	18830.74	0.0278	357.41	0.98	1074.39
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roofing																				
Howe type truss to be designed by supplier for 7 m span	planing, beam, softwood, air dried	RoW	m^3	1.22	609.68	m^3	1.00	1.22	105.2800	128.37	0.6861	0.84	5.8563	7.14	1666.1729	2031.66	39.9590	48.72	0.00	0.00
114x38 wall plate including beam filling	planing, beam, softwood, air dried	RoW	m^3	0.11	56.32	m^3	1.00	0.11	105.2800	11.86	0.6861	0.08	5.8563	0.66	1666.1729	187.66	39.9590	4.50	0.00	0.00
50x76 mm purlins on edge at maximum 1.2 m spacing	planing, beam, softwood, air dried	RoW	m^3	0.40	197.60	m^3	1.00	0.40	105.2800	41.61	0.6861	0.27	5.8563	2.31	1666.1729	658.47	39.9590	15.79	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	10483.69	104836.95	tkm	1.00	10483.69	0.53068	5563.49	0.0030851	32.34	0.0062793	65.83	8.694566	91151.18	0.22901	2400.87		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	43.27		tkm	1.00	43.27	0.53068	22.96	0.0030851	0.13	0.0062793	0.27	8.694566	376.20	0.22901	9.91		
Sub-Totals																		4913.09		4326.85
PRE-USE PHASE IMPACT										27149.96		139.94		355.32		296076.24				9239.93

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Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation: Waste from Production		EI_5: Waste Generation: Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
USE PHASE																				
REPLACEMENT OF PARTS																				
External walls (160mm)																				
Plaster, both sides (40mm)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	179.60	16522.91	kg	92.00 [5]	16522.91	0.26	4346.77	0.00	12.23	0.00	25.66	1.57	25911.43	0.01	118.14	0.08	185.88
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	4:1 ratio [silica sand production : cement production, Portland]	RoW	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.2631	1010.23	0.0007	2.84	0.0016	5.96	1.5682	6022.07	0.0072	27.46	0.05	115.20
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	gypsum plasterboard production	RoW	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.3901	202.35	0.0026	1.35	0.0065	3.36	5.1088	2649.95	0.0239	12.39	0.15	129.58
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	glass wool mat production	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	2.717	1434.03	0.021513	11.35	0.064579	34.08	49.498325	26125.22	0.20576	108.60	0.00	0.00
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	2.5994	1318.85	0.0127	6.42	0.0681	34.57	39.9104	20249.26	0.8821	447.57	0.00	47.04
"Zincalume" based steel sheeting	zinc coating, coils	RoW	m^2	100.87		m^2	1.00	100.87	5.3066	535.27	0.30194	30.46	0.56793	57.29	106.3937	10731.77	0.2808	28.32	0.00	0.00
Ridge cappings 450 mm girth	steel production, low-alloyed, hot rolled; sheet rolling, steel	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	2.5994	76.49	0.0127	0.37	0.0681	2.01	39.9104	1174.38	0.8821	25.96	0.00	0.00
galvanised	zinc coating, coils	RoW	m^2	5.85		m^2	1.00	5.85	5.3066	31.04	0.30194	1.77	0.56793	3.32	106.3937	622.40	0.2808	1.64	0.00	0.00
Additonal Transport - from factory (100km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	2194.63	21946.29	tkm	1.00	2194.63	0.53068	1164.65	0.0030851	6.77	0.0062793	13.78	8.694566	19081.35	0.22901	502.59		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	4.78		tkm	1.00	4.78	0.53068	2.54	0.0030851	0.01	0.0062793	0.03	8.694566	41.53	0.22901	1.09		
DISPOSAL OF OLD PARTS																				
External walls (160mm)																				
Plaster, both sides (40mm)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	179.60	16522.91	kg	92.00 [5]	16522.91	0.0087	144.17	0.0001	1.13	0.0001	2.18	0.2363	3904.99	1.0022	16559.26		
Internal Walls 90 mm																				
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation																				
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.0055	2.90	0.0000	0.03	0.0001	0.05	0.1829	96.54	0.9997	527.62		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	100.87	228.32	kg	2.26 [8]	228.32	0.0018	0.42	0.0000	0.00	0.0000	0.01	0.0281	6.40	0.0001	0.01		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	221.45	22145.18	tkm	1.00	221.45	0.53068	117.52	0.0030851	0.68	0.0062793	1.39	8.694566	1925.43	0.22901	50.71		
Sub-Totals: Materials										10428.01		88.62		184.34		119637.89		22780.55		477.71
Use Phase: Maintenance Impact	Number of maintenance cycles:	1								10428.01		88.62		184.34		119637.89				23258.25
Electricty for Heating/Cooling	electricity production, hard coal	ZA	kWh/a	3527.78		kWh	1.00	3527.780015	1.1186	3946.17	0.011452	40.40	0.032065	113.12	15.4220204	54405.50	0.0051195	18.06		
Use Phase: Operation Impact	Design working life (years):	30								118385.24		1212.00		3393.55		1632164.86				541.81
USE PHASE IMPACT										128813.25		1300.62		3577.89		1751802.75				23800.07

SANS 10400-XA House: 09 Ikhaya Future House

Materials						Conversion			EI_1: Carbon Footprint		EI_2: Acidification Potential		EI_3: Eutrophication Potential		EI_4: Resource Depletion		EI_5: Waste Generation – Waste from Production		EI_5: Waste Generation – Construction Waste	
Item	Ecoinvent Equivalent	Loc	Unit	Quantity	Mass [kg]	Ecoinvent unit	Conversion factor	New Value	[kg CO_{2e}/unit]	[kg CO_{2e}/item]	[kg SO_{2e}/unit]	[kg SO_{2e}/item]	[kg NO_3^-/unit]	[kg NO_3^-/item]	[MJ-eq/unit]	[MJ-eq/item]	[kg/unit]	[kg/item]	[m^3/item]	[kg/item]
END-OF-LIFE PHASE																				
Foundations																				
10 MPa concrete foundation (600x200mm)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	7.32	17568.00	kg	2400.00 [5]	17568.00	0.0129	226.47	0.0001	1.90	0.00020334	3.57	0.3015	5296.36	1.0022	17606.65		
Reinforcing (4 x Y12)	treatment of waste reinforcement steel, collection for final disposal	CH	kg	68.95	68.95	kg	1.00	68.95	0.1512	10.42	0.0010	0.07	0.020793	1.43	2.1420	147.70	0.2136	14.73		
190 mm solid blockwork (foundation wall)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	16.00	4560.00	kg	285.00 [1]	4560.00	0.0129	58.78	0.0001	0.49	0.0002	0.93	0.3015	1374.74	1.0022	4570.03		
400x210mm strip footing	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	3.36	7392.00	kg	2200.00 [1]	7392.00	0.0129	95.29	0.0001	0.80	0.0002	1.50	0.3015	2228.52	1.0022	7408.26		
brickforce (75x2.8mm)	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	80.00	8.72	kg	0.11 [2]	8.72	0.0018	0.02	0.0000	0.00	0.0000	0.00	0.0281	0.24	0.0001	0.00		
										0.00		0.00		0.00		0.00		0.00		
Floor Slab										0.00		0.00		0.00		0.00		0.00		
Damp proof membrane 250 micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m^2	91.00	20.93	kg	0.23 [3]	20.93	0.3839	8.03	0.0001	0.00	0.0040	0.08	0.3704	7.75	0.9129	19.11		
25 MPa concrete (power floated)	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^3	9.10	21840.00	kg	2400.00 [5]	21840.00	0.0129	281.54	0.0001	2.36	0.0002	4.44	0.3015	6584.28	1.0022	21888.05		
steel mesh ref 193	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	91.00	175.63	kg	1.93 [4]	175.63	0.1512	26.55	0.0010	0.17	0.0208	3.65	2.1420	376.19	0.2136	37.51		
										0.00		0.00		0.00		0.00		0.00		
External walls (160mm)																				
Expanded polystyrene core (80mm)	treatment of waste expanded polystyrene, municipal incineration	RoW	m^3	7.18	114.94	kg	16.00 [19]	114.94	3.1735	364.77	0.0004	0.05	0.0010	0.11	0.4013	46.12	0.0319	3.67		
Weldmesh, both sides (100x100x3.5mm)	treatment of waste reinforcement steel, collection for final disposal	CH	m^2	179.60	280.17	kg	1.56 [4]	280.17	0.1512	42.36	0.0010	0.27	0.0208	5.83	2.1420	600.12	0.2136	59.83		
Plaster, both sides (40mm)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	179.60	16522.91	kg	92.00 [5]	16522.91	0.0087	144.17	0.0001	1.13	0.0001	2.18	0.2363	3904.99	1.0022	16559.26		
DPC - 375micron	treatment of waste polyethylene/polypropylene product, collection for final disposal	RoW	m	40.00	1.52	kg	0.04 [3]	1.52	0.3839	0.58	0.0001	0.00	0.0040	0.01	0.3704	0.56	0.9129	1.39		
Internal Walls 90 mm																				
Solid blockwork, mortar	treatment of waste cement in concrete and mortar, collection for final disposal	RoW	m^2	69.57	12869.85	kg	185.00 [1]	12869.85	0.0129	165.91	0.0001	1.39	0.0002	2.62	0.3015	3879.97	1.0022	12898.16		
Plaster, both sides (12mm thick)	treatment of waste mineral plaster, collection for final disposal	CH	m^2	139.13	3840.08	kg	27.60 [5]	3840.08	0.0087	33.51	0.0001	0.26	0.0001	0.51	0.2363	907.56	1.0022	3848.53		
Ceiling and Thermal Insulation										0.00		0.00		0.00		0.00		0.00		
6.4 mm gypsum plaster board	treatment of waste gypsum, sanitary landfill	CH	m^2	91.00	518.70	kg	5.70 [6]	518.70	0.0122	6.34	0.0249	12.93	0.0002	0.12	0.3342	173.37	1.0037	520.62		
145 mm glass wool laid to manufacturers specifications, finished with coverstrips (incl cornices)	treatment of waste mineral wool, inert material landfill	RoW	m^2	91.00	527.80	kg	5.80 [7]	527.80	0.005503	2.90	4.74E-05	0.03	8.70E-05	0.05	0.18291267	96.54	0.99965	527.62		
Roofing																				
Howe type truss to be designed by supplier for 7 m span	treatment of waste wood, untreated, municipal incineration	RoW	m^3	1.22	609.68	kg	500.00 [9]	609.68	0.0146	8.90	0.0002	0.10	0.0006	0.36	0.1663	101.40	0.0120	7.29		
114x38 wall plate including beam filling	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.11	56.32	kg	500.00 [9]	56.32	0.0146	0.82	0.0002	0.01	0.0006	0.03	0.1663	9.37	0.0120	0.67		
50x76 mm purlins on edge at maximum 1.2 m spacing	treatment of waste wood, untreated, municipal incineration	RoW	m^3	0.40	197.60	kg	500.00 [9]	197.60	0.0146	2.89	0.0002	0.03	0.0006	0.12	0.1663	32.86	0.0120	2.36		
Roof Covering																				
0.54 mm Fielders corrugated Colorbond G550 AZ150 anti-corrosive "Zincalume" based steel sheeting	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m^2	100.87	507.37	kg	5.03 [8]	507.37	0.0018	0.94	0.0000	0.01	0.0000	0.02	0.0281	14.23	0.0001	0.03		
Ridge cappings 450 mm girth	treatment of waste bulk iron, excluding reinforcement, sorting plant	RoW	m	13.00	29.43	kg	2.26 [8]	29.43	0.0018	0.05	0.0000	0.00	0.0000	0.00	0.0281	0.83	0.0001	0.00		
Additonal Transport - to landfill (10km)	transport, freight, lorry 3.5-7.5 metric ton, EURO3	RoW	tkm	877.11	87710.59	tkm	1.00	877.11	0.53068	465.46	0.0030851	2.71	0.0062793	5.51	8.694566	7626.06	0.22901	200.87		
Sub-Totals																		86174.63		
END-OF-LIFE PHASE IMPACT										1946.70		24.69		33.06		33409.77				86174.63
TOTAL LIFE CYCLE IMPACT										157909.91		1465.25		3966.28		2081288.76				119214.63

D10. Comparative EI Results

FIGURE D-1: EI1 RESULTS (CHANGE COMPARED TO REFERENCE DESIGN)

FIGURE D-2: EI2 RESULTS (CHANGE COMPARED TO REFERENCE DESIGN)

FIGURE D-3: EI3 RESULTS (CHANGE COMPARED TO REFERENCE DESIGN)

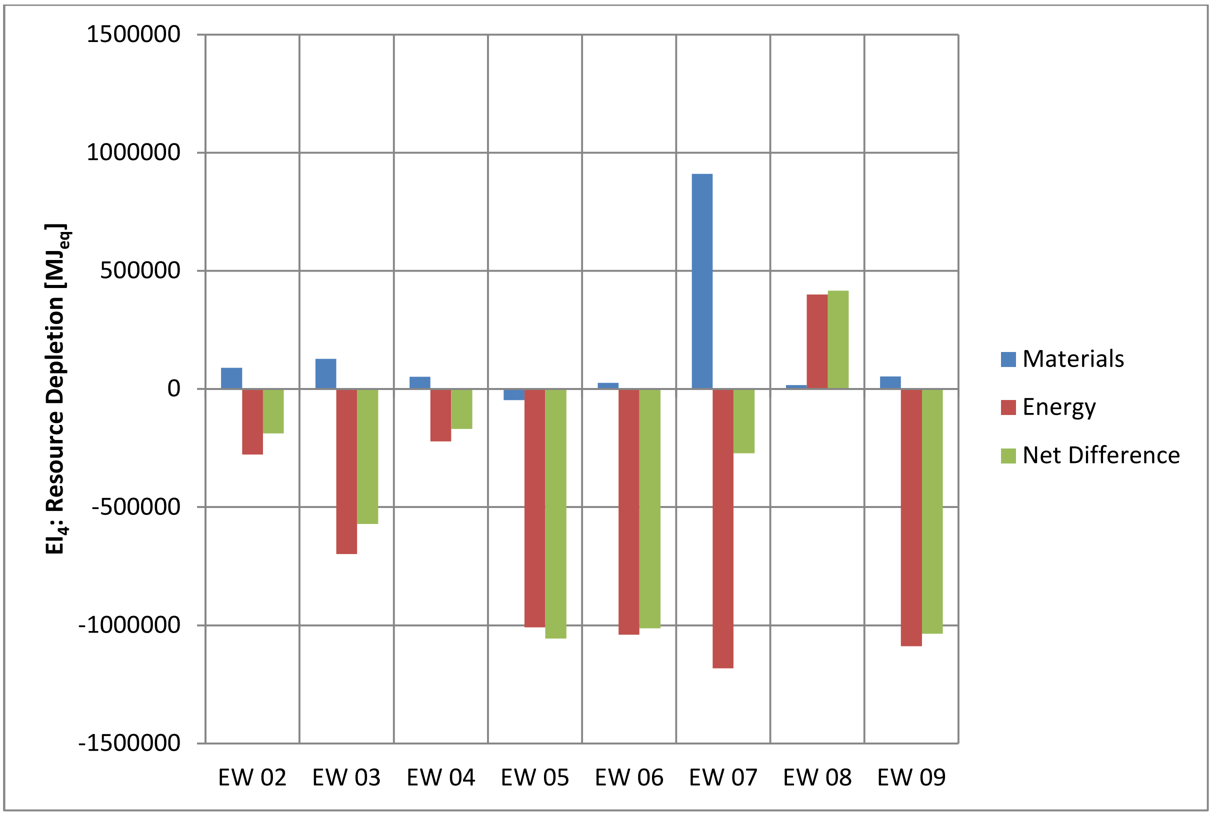

FIGURE D-4: EI4 RESULTS (CHANGE COMPARED TO REFERENCE DESIGN)

FIGURE D-5: EI5 RESULTS (CHANGE COMPARED TO REFERENCE DESIGN)

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Appendix E: Complete Sensitivity Analyses Results

E1. Additional Transport Distances (To Construction Site)

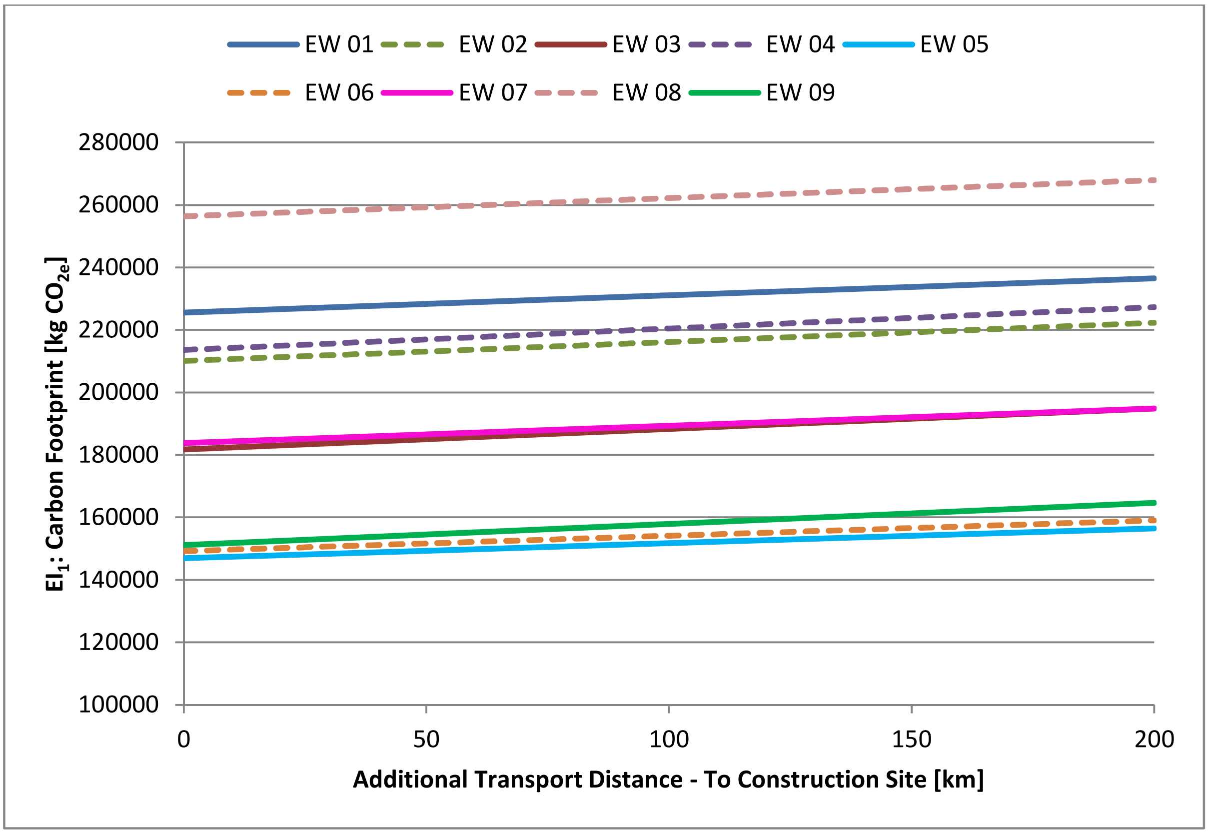

FIGURE E-1: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE SENSITIVITY – EI1

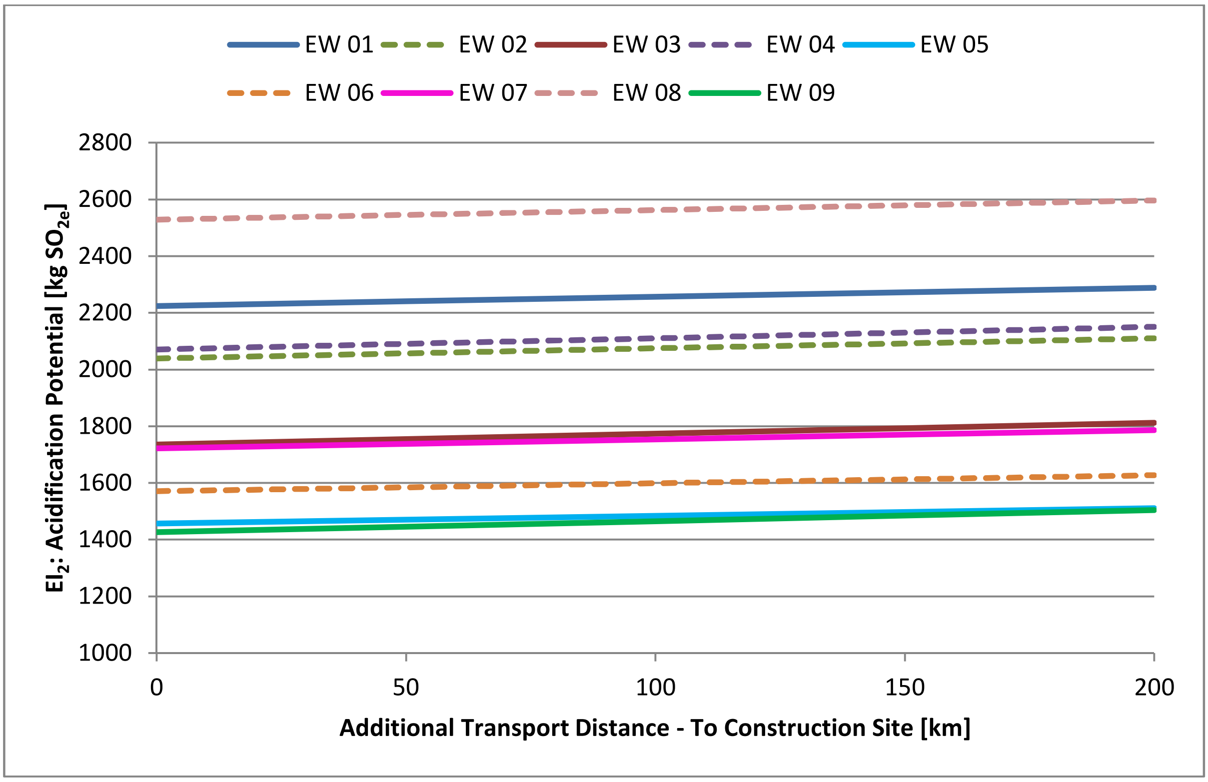

FIGURE E-2: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE SENSITIVITY – EI2

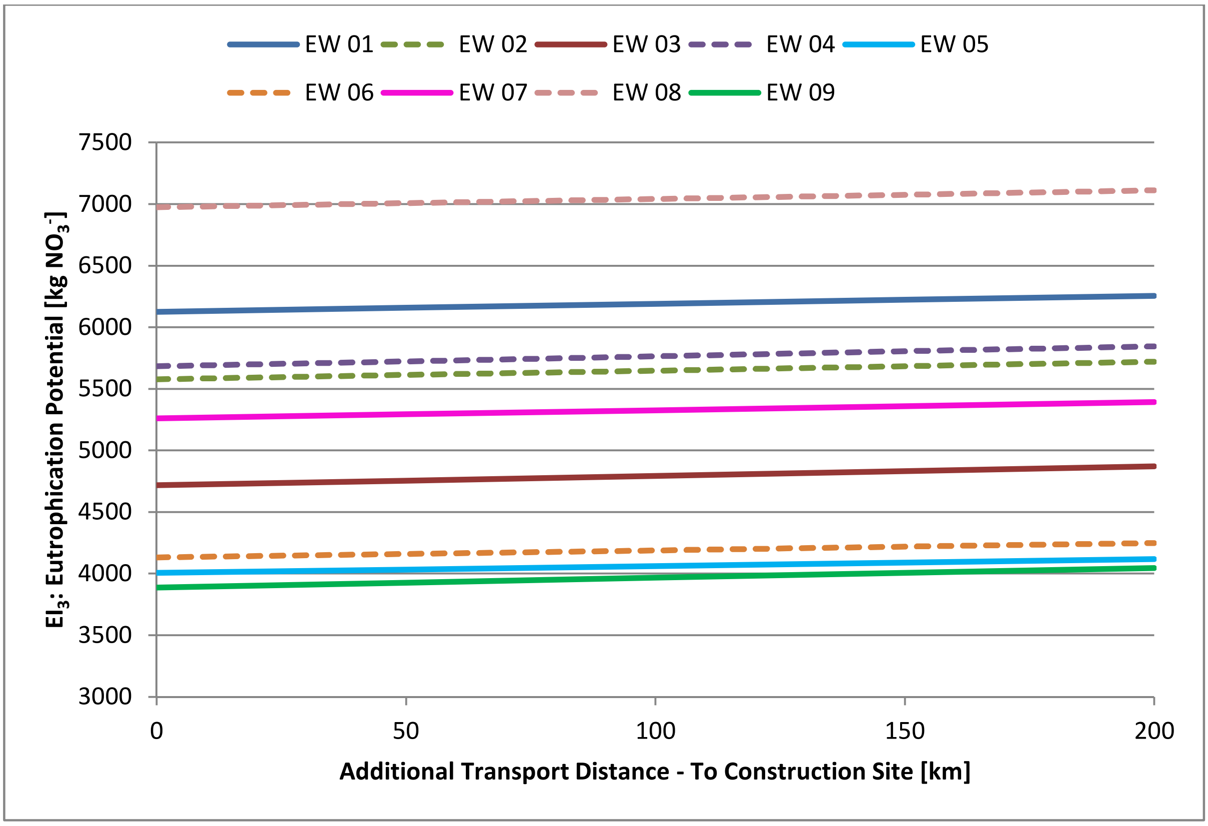

FIGURE E-3: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE SENSITIVITY – EI3

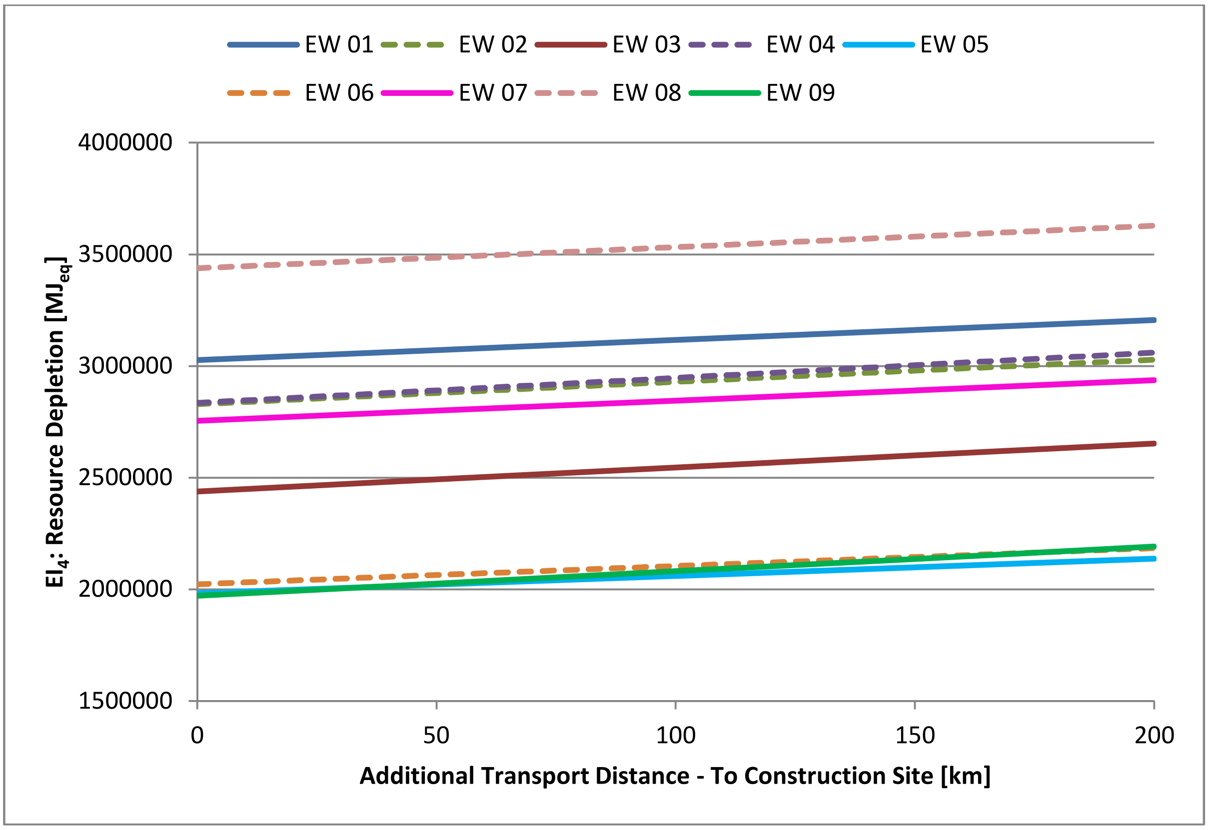

FIGURE E-4: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE SENSITIVITY – EI4

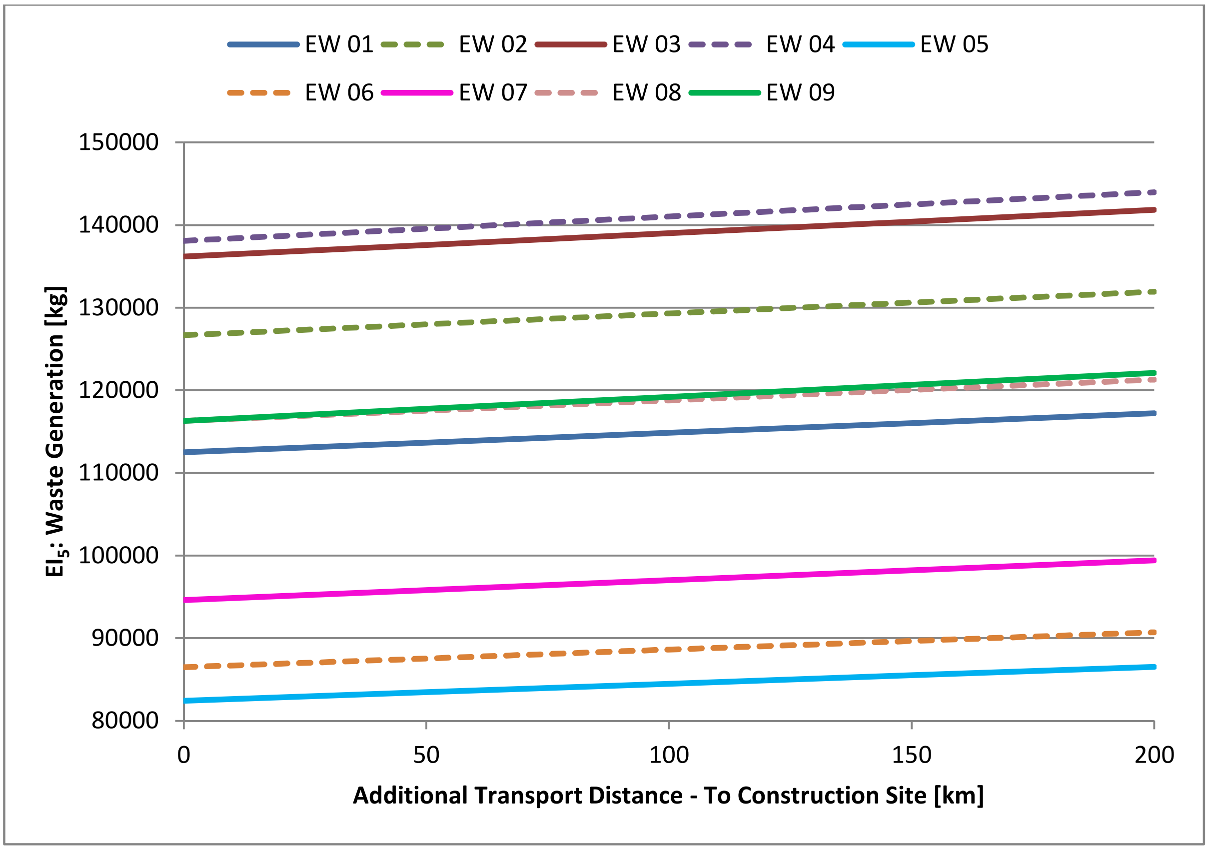

FIGURE E-5: ADDITIONAL TRANSPORT TO CONSTRUCTION SITE SENSITIVITY – EI5

E2. Additional Transport Distances (To Disposal)

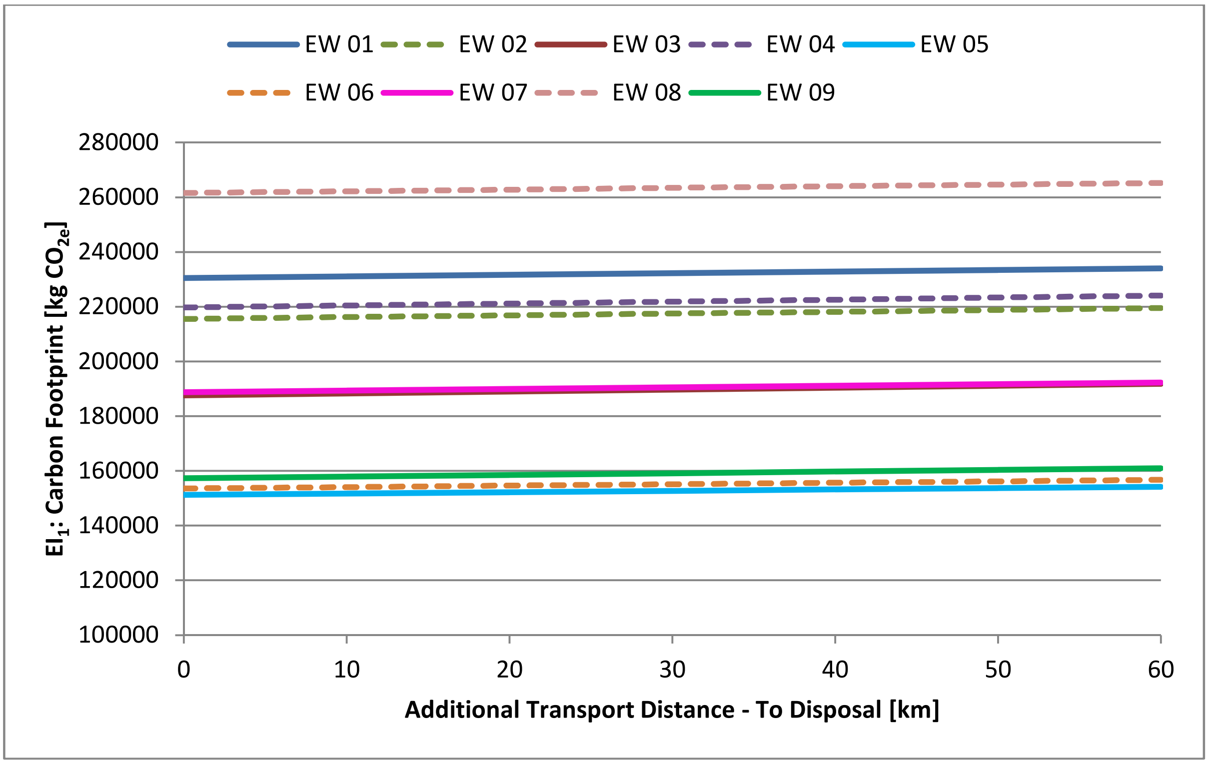

FIGURE E-6: ADDITIONAL TRANSPORT TO DISPOSAL SENSITIVITY - EI1

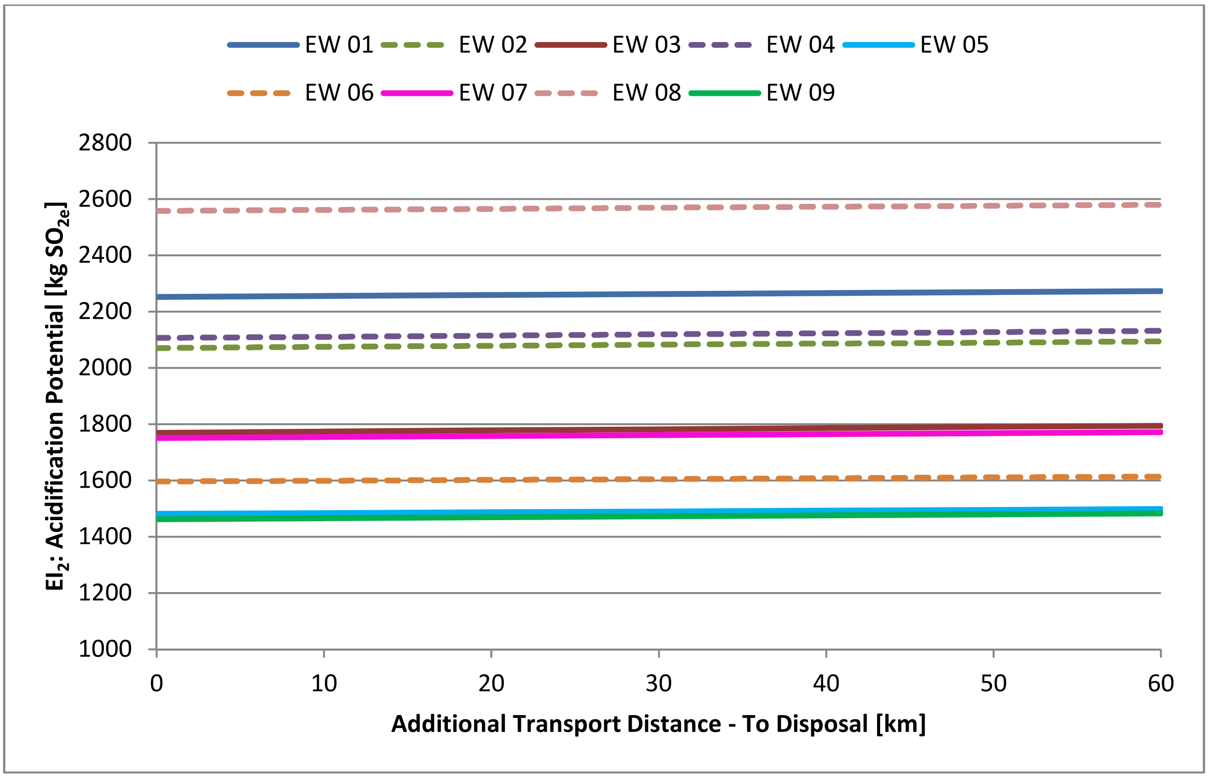

FIGURE E-7: ADDITIONAL TRANSPORT TO DISPOSAL SENSITIVITY - EI2

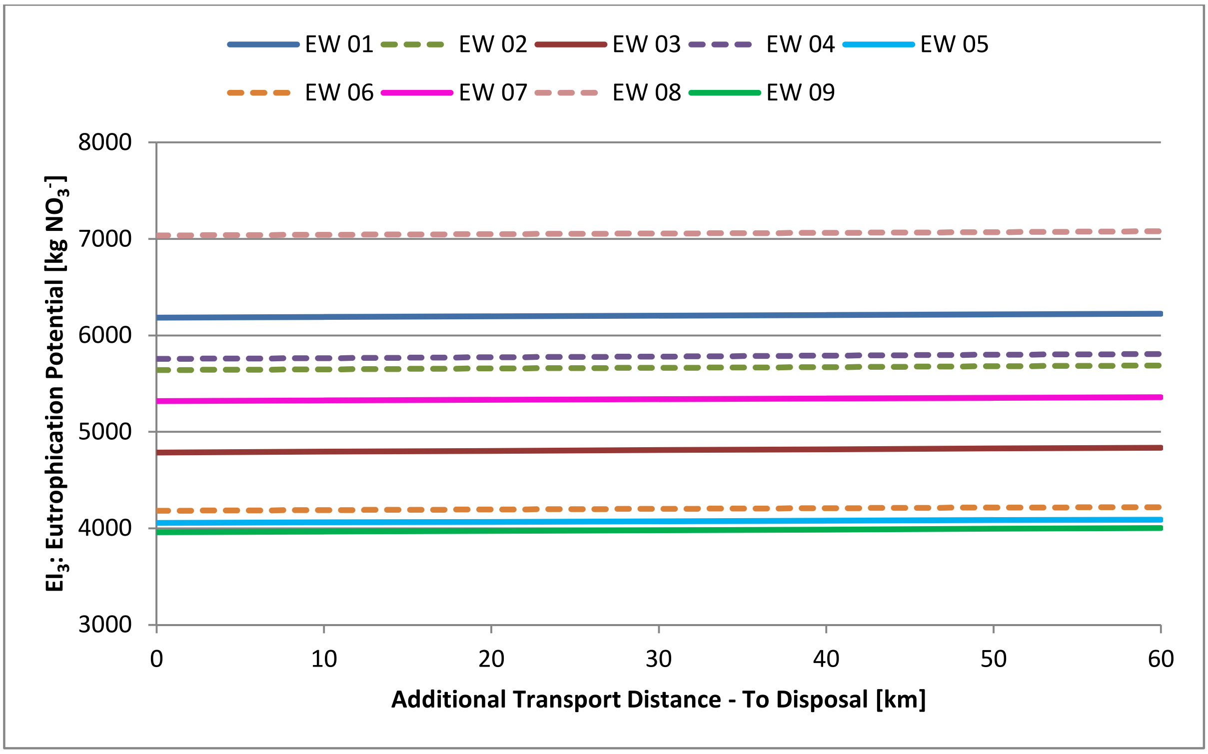

FIGURE E-8: ADDITIONAL TRANSPORT TO DISPOSAL SENSITIVITY - EI3

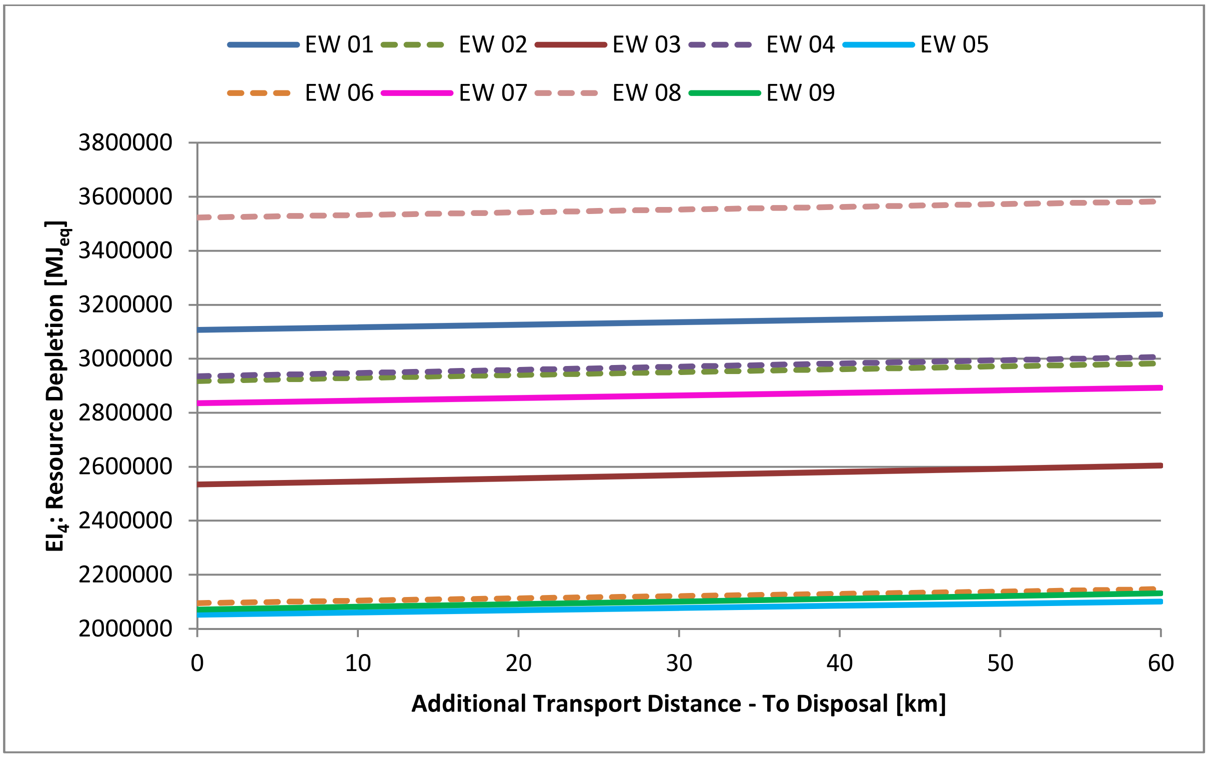

FIGURE E-9: ADDITIONAL TRANSPORT TO DISPOSAL SENSITIVITY - EI4

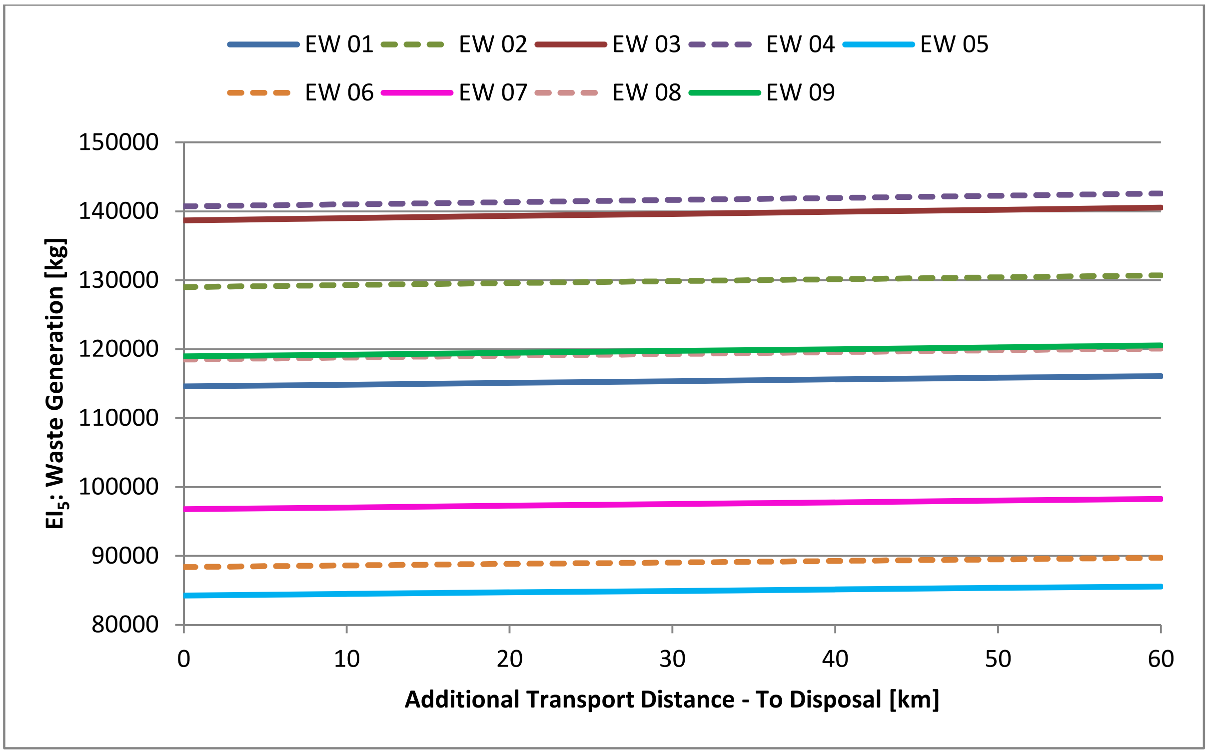

FIGURE E-10: ADDITIONAL TRANSPORT TO DISPOSAL SENSITIVITY - EI5

E3. DWL Sensitivity Analysis

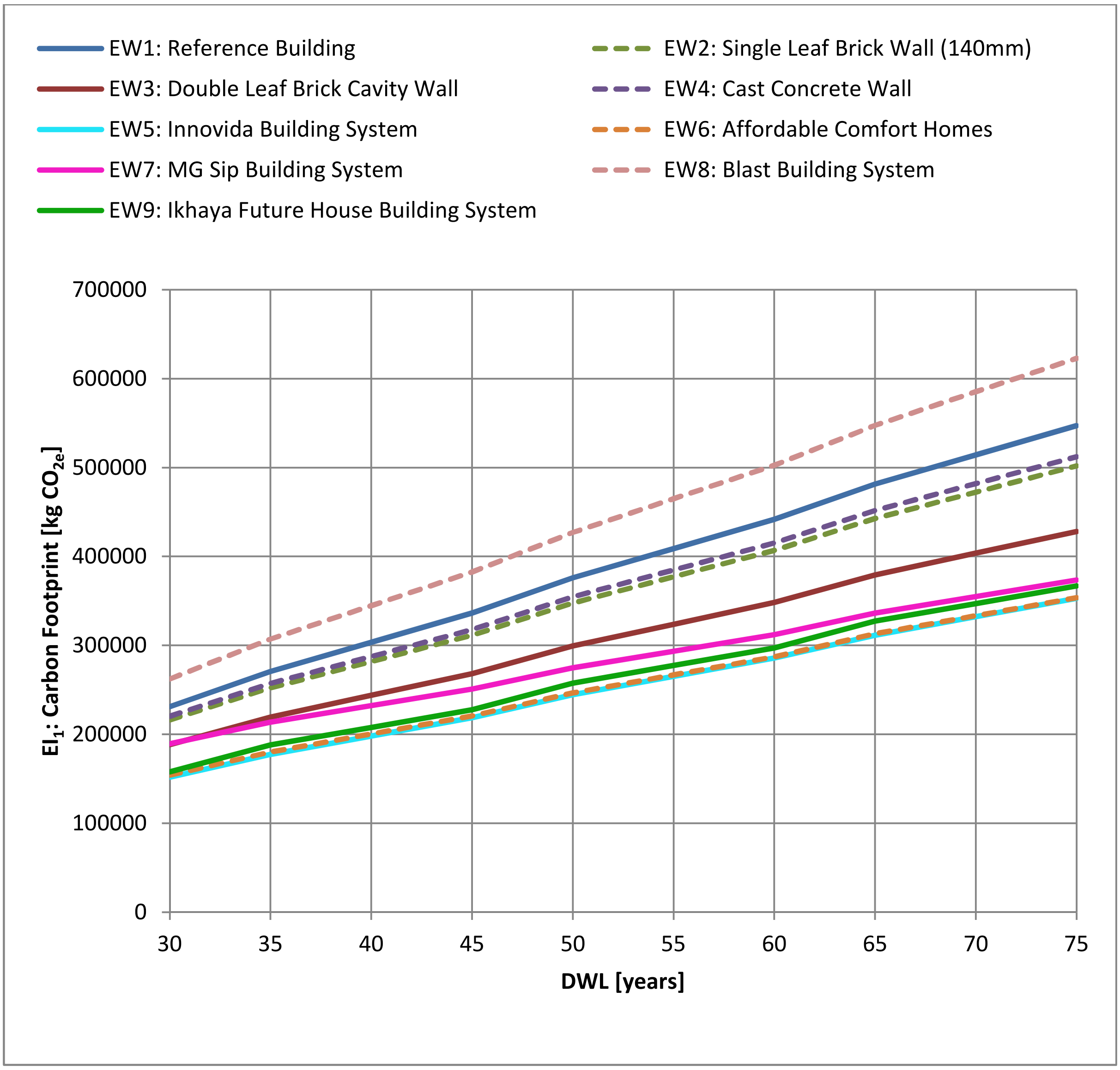

FIGURE E-11: DWL SENSITIVITY - EI1

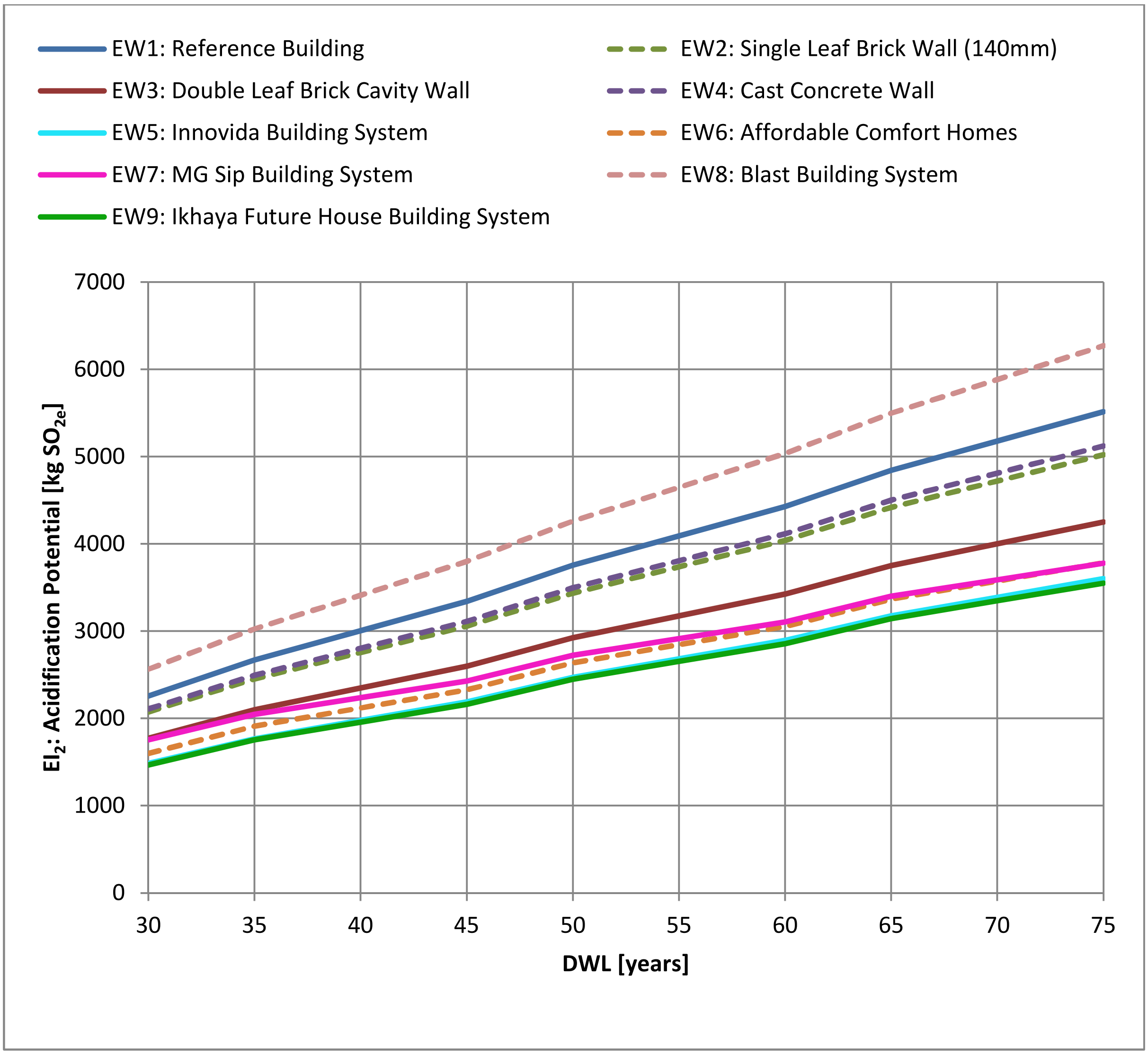

FIGURE E-12: DWL SENSITIVITY - EI2

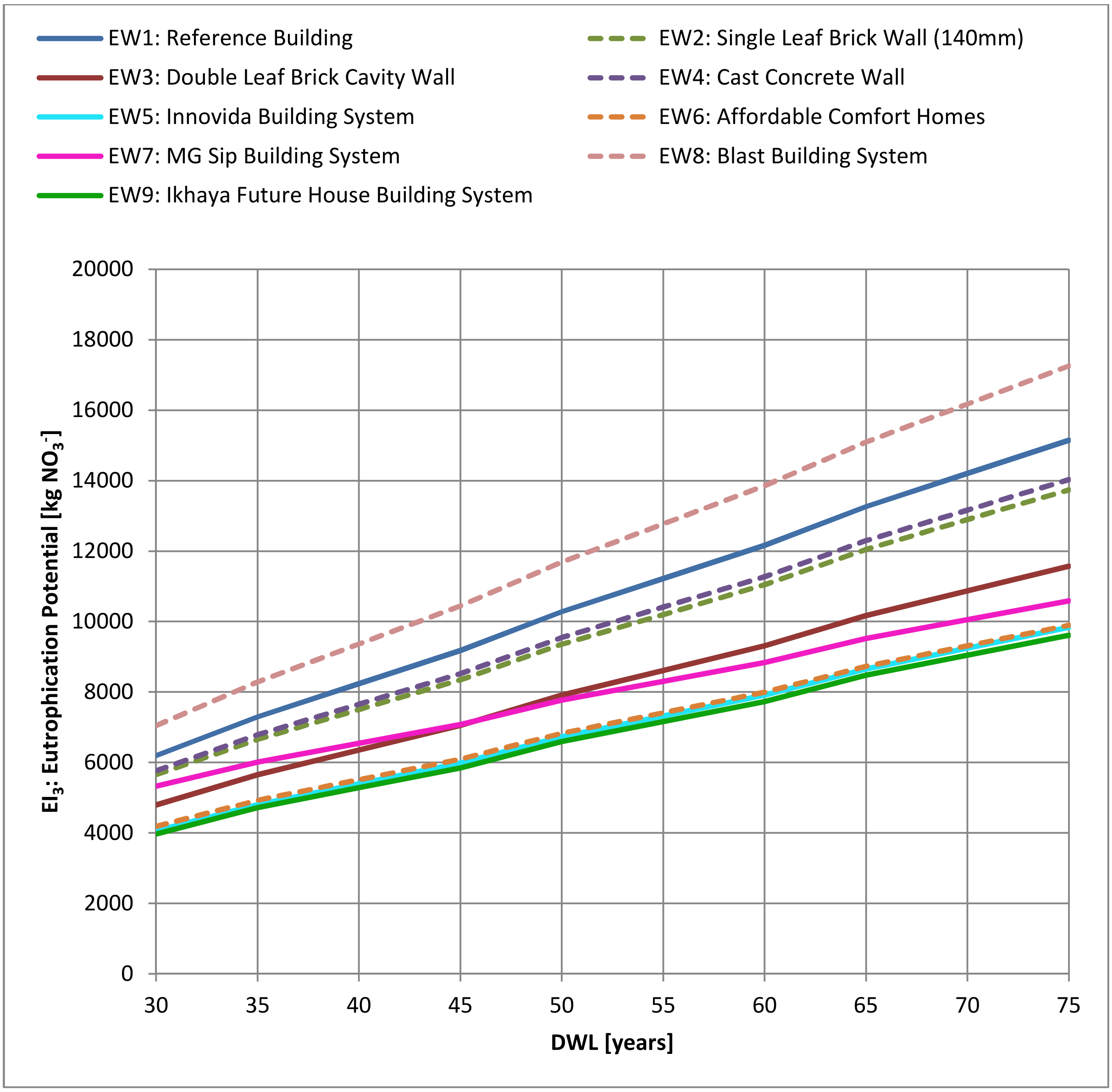

FIGURE E-13: DWL SENSITIVITY - EI3

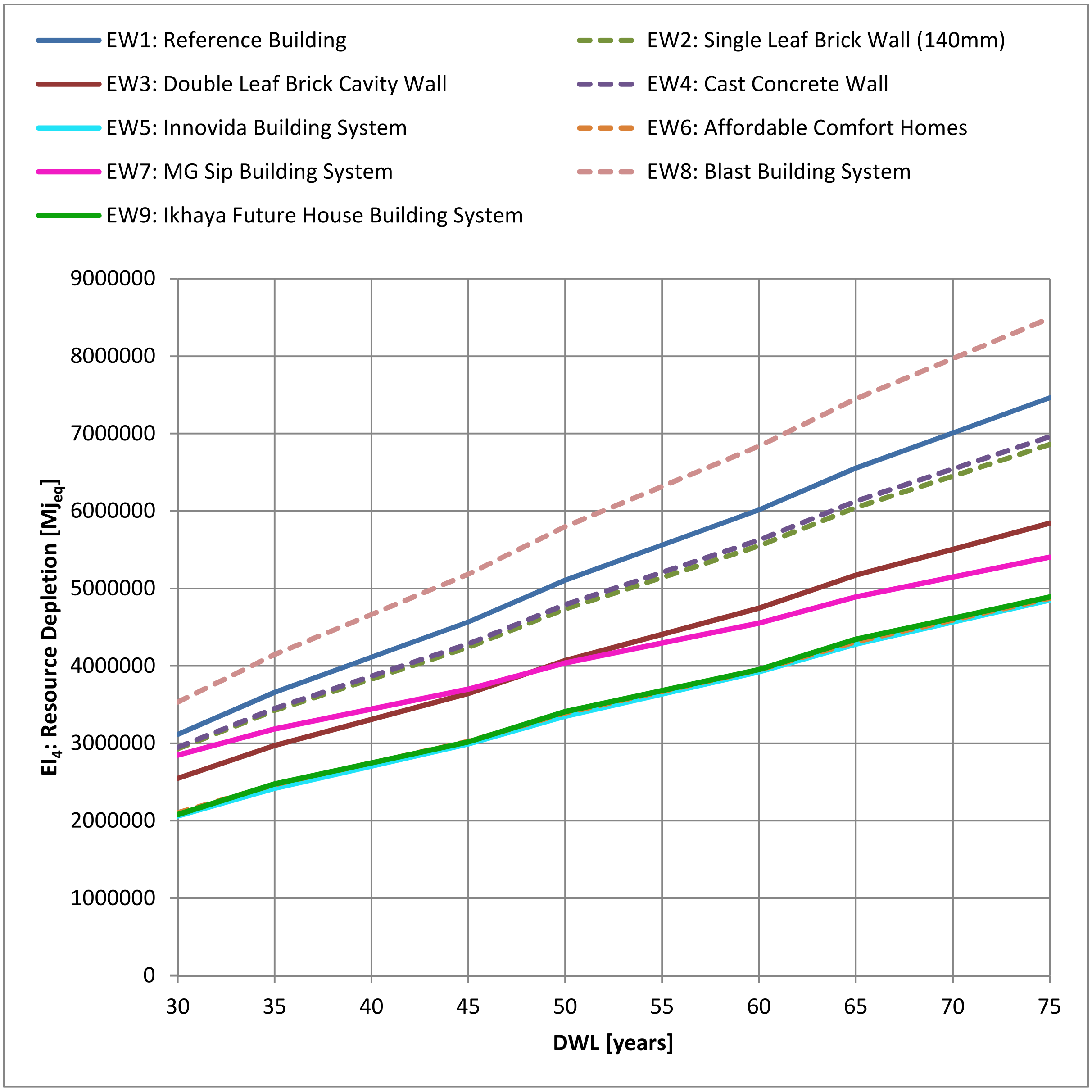

FIGURE E-14: DWL SENSITIVITY - EI4

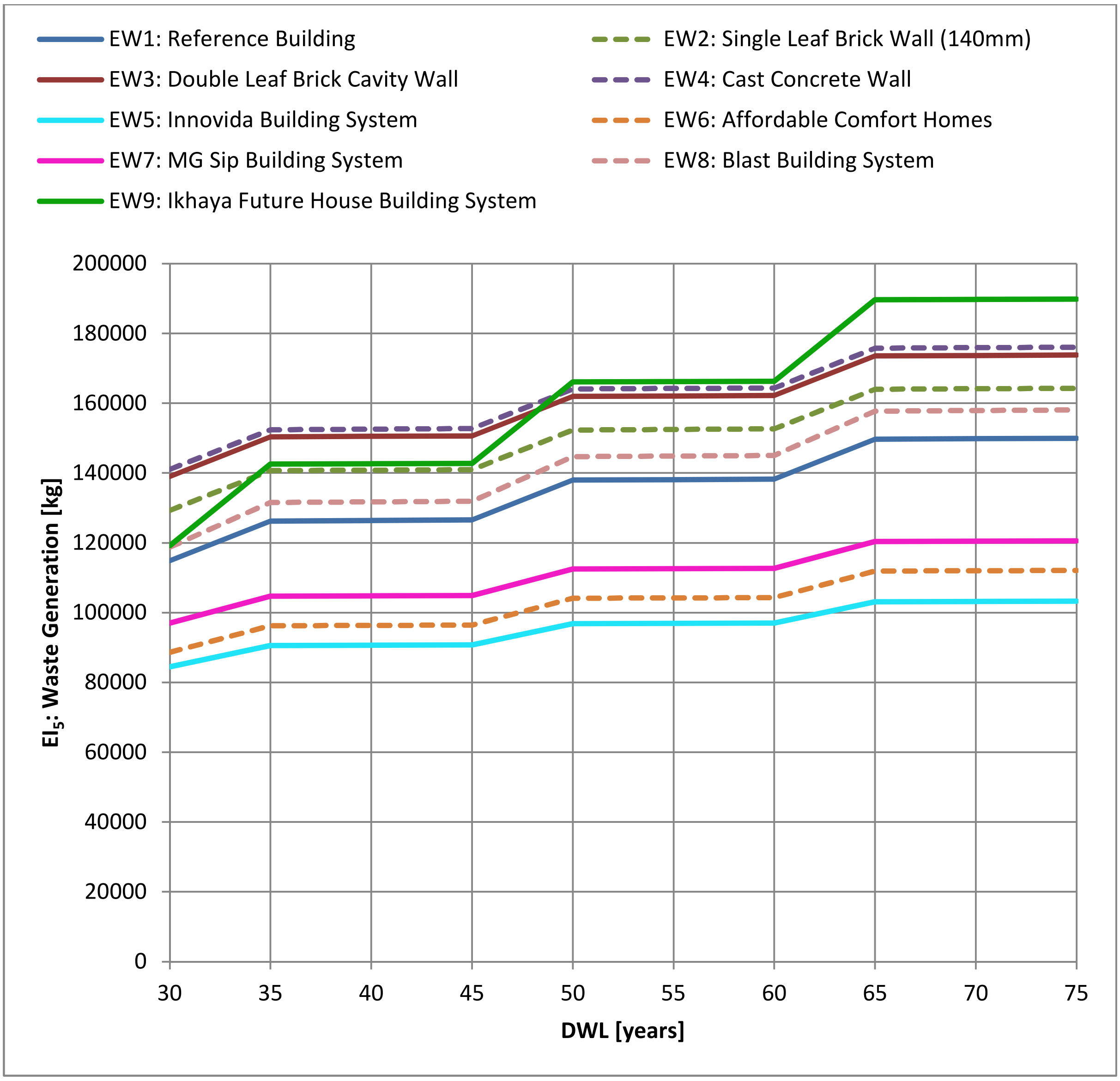

FIGURE E-15: DWL SENSITIVITY - EI5

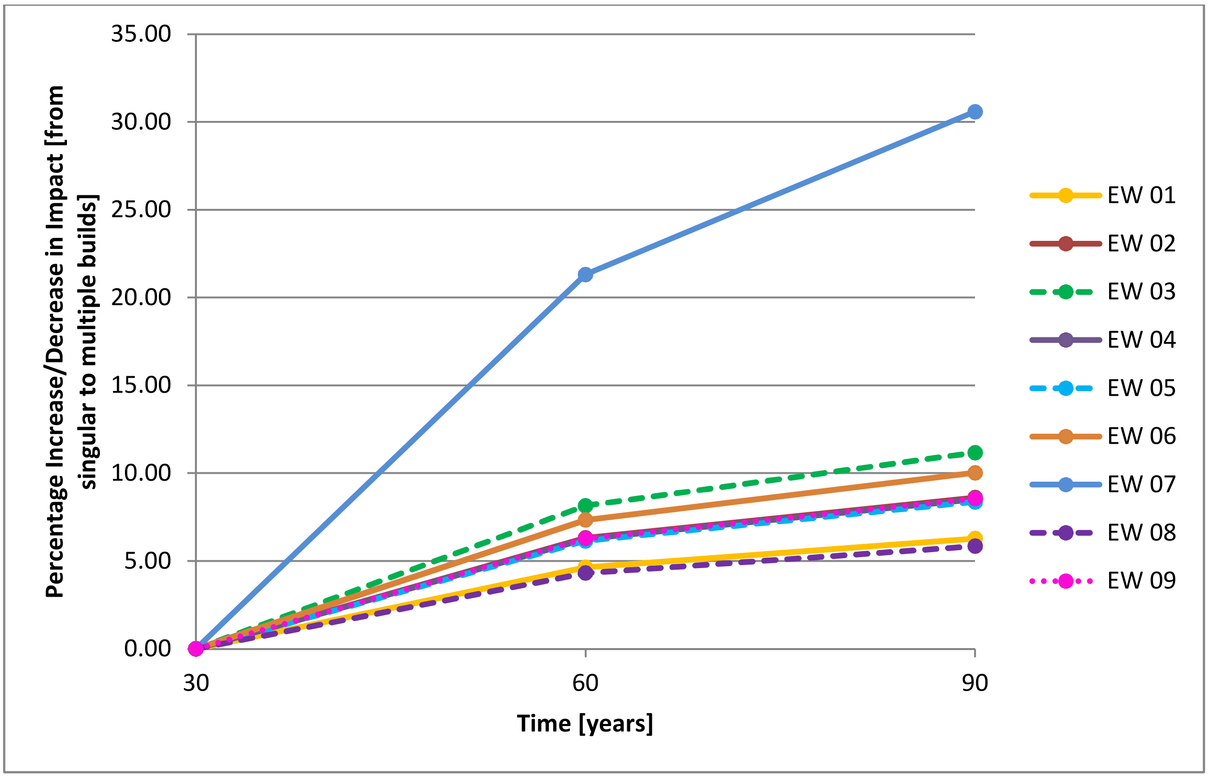

FIGURE E-16: DWL - SINGLE-BUILD VS MULTIPLE-BUILD STRUCTURES (EI1)

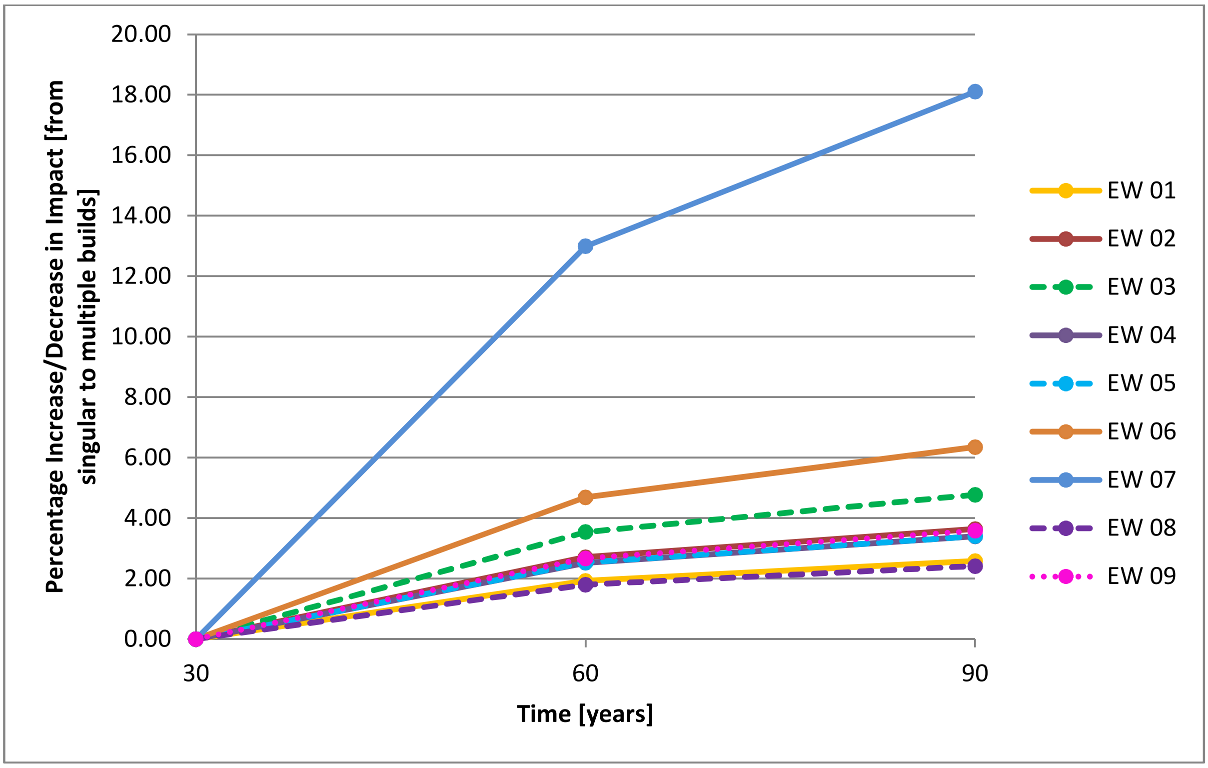

FIGURE E-17: DWL – SINGLE-BUILD VS MULTIPLE-BUILD STRUCTURES (EI2)

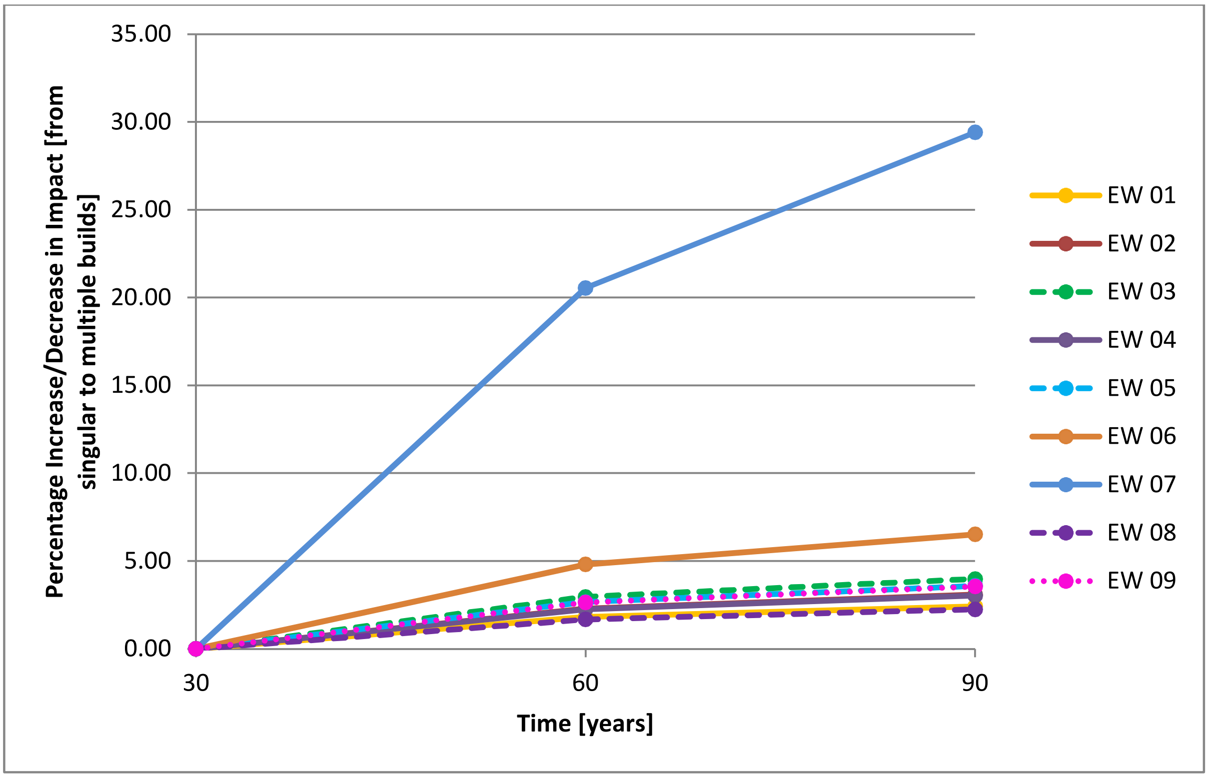

FIGURE E-18: DWL – SINGLE-BUILD VS MULTIPLE-BUILD STRUCTURES (EI3)

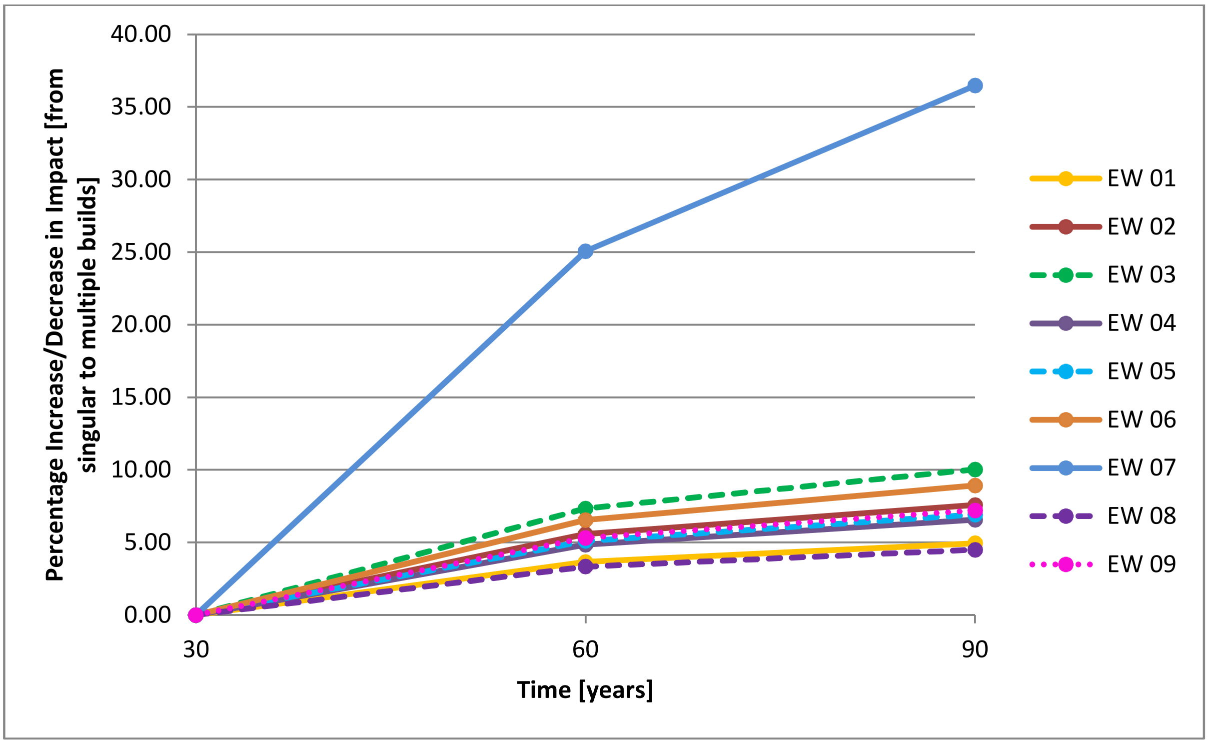

FIGURE E-19: DWL – SINGLE-BUILD VS MULTIPLE-BUILD STRUCTURES (EI4)

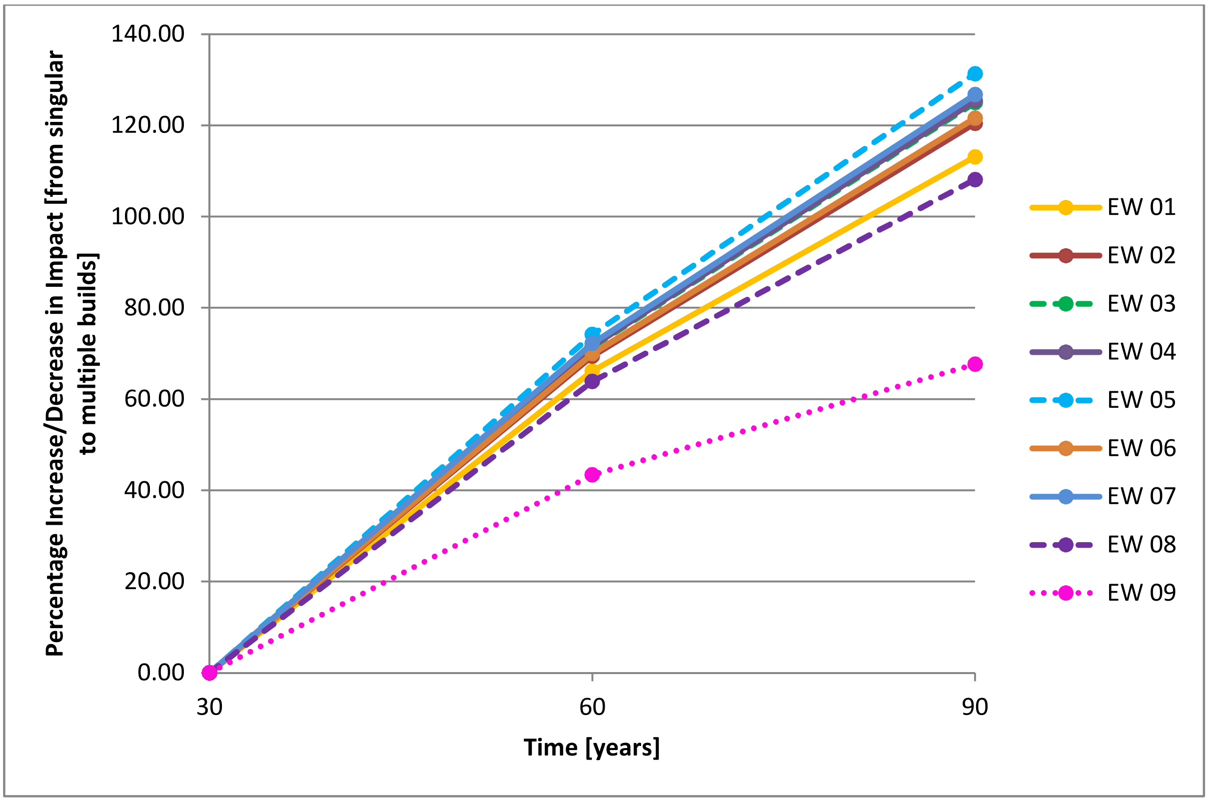

FIGURE E-20: DWL – SINGLE-BUILD VS MULTIPLE-BUILD STRUCTURES (EI5)