Global Warming Potential of Mass Housing Development: The Case of Sunshine Real Estate in Addis Ababa

Betelhem Woldu

A Thesis Submitted to

The department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Masters in Environmental Architecture

Office of Graduate Studies

Adama Science and Technology University

March, 2023

Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled ‘Global warming potential of Mass housing development: The case of Sunshine real estate in Addis Ababa” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

___Betelhem Woldu_________ ________________________ ________________

Name of student Signature Date

Recommendation of Advisor

I, the advisor of this thesis, hereby certify that I/we have read the revised version of the thesis entitled "Global warming potential of Mass housing development: The case of Sunshine real estate in Addis Ababa" prepared under my/our guidance by Betelhem Woldu submitted in partial fulfillment of the requirements for the degree of Maters of Science in Environmental Architecture. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

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Approval Page of M.Sc. Thesis

I/we, the advisors of the thesis entitled "Global warming potential of Mass housing development: The case of Sun shine real estate in Addis Ababa" and Developed by Betelhem Woldu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Betelhem Woldu have read and evaluated the thesis entitled "Global warming potential of Mass housing development: The case of Sun shine real estate development" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Environmental Architecture.

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LIST OF ACRONYM

AEC Architecture Engineering Construction

BHK Bedroom Housing & Kitchen

BOQ Bill of Quantity

CO2 Carbon Dioxide

EPA Environmental Protection Authority

EPD Environmental Product Declarations

GWP Global Warming Potential

HVAC Heating Ventilation and Air Conditioning

IEA Integrated Environmental Assessment

ISO International Organization for Standardization

LCA Life Cycle Assessment

LEED Leadership in Energy and Environmental Design

ABSTRACT

Building has a large contribution to the impact on the environment. One of the main impacts comes from CO2 in materials used for building construction. In Addis Ababa, it is observed 99.9% of buildings are concrete structures. The transportation of raw materials for concrete and the production of cement emits a high amount of CO2 into the surrounding atmosphere. And it is considered one of the environmental impact buildings has on the environment. This study aims to assess the environmental impact of mass housing development in terms of GWP. For this purpose, the Life Cycle Assessment (LCA) methodology was chosen, based on ISO 14040 guidelines, It was applied with the available database of the materials to be used and LCA software to calculate impacts and assess the situation Analyzing real estate's building technologies. The LCA of this study shows that concrete structures are heavily used, with a proportional impact on the environment. It was also shown that mass housing as single-unit residential buildings has higher GWP than apartment buildings with the same rate of occupants. Recommendation for mass-housing projects in the design stage regarding lower GWP was suggested using the methodology of this research.

Key words: Environmental impact, Global warming potential, Life cycle assessment, Mass housing, Real estate

CHAPTER ONE

1. INTRODUCTION

Mass housing is a solution which Ethiopia and most other developing countries take up as a solution to their housing problems. But in most of these mass housing environments, neither the Design nor the operation of households consider the impacts up on the environmental. This coupled with other factors will not only affect the surrounding of mass housing but also affects the environment of the country as a whole in one way or the other.

The study is conducted to point out the impacts of housing developments mostly considers on the group projects which are mass housing development. As seen from the more recent years a lot of real estates has been emerging to address the issue of housing in Addis Ababa. Life cycle assessment is commonly used in assessing the environmental impact of buildings at different levels with varying emphasis on different aspects.

1.1 BACKGROUND

House is one of the basic necessity of human being. A house is literally defined as buildings or structures that provide cover from weather or protection against danger, a building in which people live, a dwelling etc. (Majale & Tipple, 2002). And as the population is increasing daily the need of house is also increasing. Mass housing has taken a solution and most developing countries take up it as a way to solve their housing problems.

Environmental sustainability highlights the issues of climate change and the reduction in greenhouse gas emissions. These macro-objectives can be achieved by minimizing the energy demand of buildings through using passive design strategies and energy efficiency in the HVAC systems and that of renewable energy sources. The amount of embodied energy of construction material should also be considered and minimized. It also requires to minimize use of fresh water, minimize pollution, minimize waste, and minimize use of resources, appropriate land use, Protect natural ecosystems, Good accessibility, Mitigation. (Del Pero, Bellini, Martire, & di Summa, 2021)

In the past, development endeavors did not consider environmental issues in the evaluation of development projects. In other words, decision-making about implementation of development projects was merely focused on short-term technical feasibility and economic benefits. (Ali, 2009) (Kahangirwe, 2012) This negligence and unwise utilization of the natural resources resulted in degradation of the environment and scarcity of the resources (Laedre, 2015) (Retief, 2014). Divers studies focusing at building level environmental performance have explored the circular economy for buildings and building elements, construction waste optimizations, integrated design, parametric design and building optimization, building rehabilitation, refurbishment and repurposing, embodied environmental cost, design for disassembly. (Hossain, 2018) (Eberharted, 2019) (Szalay Z, 2019). Although studies have looked for solutions and insight at scales larger than a buildings this study address the issue for a real estate in the case Addis Ababa.

The manufacture, transport, and installation for a building made of materials such as steel, concrete, and glass require a large quantity of energy, even though they represent a small part of the ultimate cost of the building as a whole. (I. Z. Bribian, 2009) Architecturally thinking building designs should be friendly to the environment. By minimizing the footprint of the development site, by selection of materials in overall design of building that minimize the overall impact on the environment. (Stang A. and Hawthorne, 2005) This points make a whole lot of difference if applied to mass housing system.

As in most developing countries in Africa, Ethiopia is experiencing an expansive urban growth. This urban growth causes excessive pressure on the existing infrastructure, which affects buildings, public transportation, road networks, water quality, waste collection, public health, and overall energy usage. One solution to address the housing need of the society was mass housing. In the concept of mass housing Over 125,000 condos are under construction in Addis Ababa, Ethiopia. (Monitor, 2020). There are also many private real estate developments that are taking place in large scale (large plot area). The environmental impact assessment guideline document of Ethiopia recommends that housing development covering an area of 50 hectares or more require full EIA as they have adverse and significant environmental impacts (EPA, 2000) (EPA, 2003) The real-estate development selected for this study doesn’t cover as much but has a significant impact on the environment.

LCA is one tool used to assess impact on the environment. It is a methodology that has been developed to evaluate the environmental impact of buildings, with respect to their processes, their materials and use (energy) throughout the whole life cycle of a building. The first step in calculating LCA is defining the goal and Scope based on the needed outcome the using collecting data required for interpretation of results. Then using tools to calculate (in this study One click LCA tool is used) an output for Environmental impact. Below is a general methodology of LCA in building.

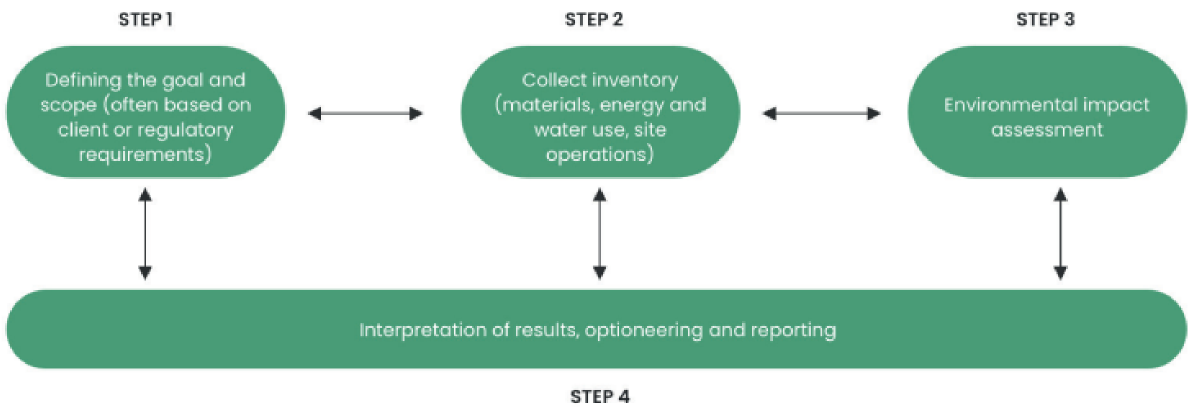

FIGURE 1 Steps involved in conducting a building LCA

Project stage	LCA uses
Concept stage	Advantageous at this stage in -More carbon savings - Very high flexibility - Ability to set targets and make major choices
Detailed design stage	Applied for - Comparisons between different design alternatives - Carbon benchmarking
Construction and procurement stage	Purposed for - Detailed LCA for certifications - Comply with regulations

Table 1 Summary of LCA requirement for various project stages

1.2 STATEMENT OF PROBLEM

Buildings are one of the largest consumers of natural resources in their life span (construction, operation, maintenance, and demolishing). (Del Pero, Bellini, Martire, & di Summa, 2021). Mass housing is built on a large scale to minimize the housing problem of society. This means most are similar typologies with aim of providing a roof over the head. It is growing very fast in Addis Ababa, Ethiopia, as a real estate or a governmental condominium project. This rapid housing development causes a high release of carbon footprint and a negative impact on the environment. As they are being built on open land, farmland, or deforestation of a forest area.

FIGURE 2 before and after image of Gerji and Meri luke Site (source: Google maps)

Sunshine real estate development has taken about 392,000m2 land in four different sites for housing development. The PLC has planned to build around 600 residential buildings. About 243 residential units have been completed and handed over to residents. The area where sunshine real-estate is built was an open area before. Now it's covered with residential units that also duplicate nature in a way with every material used. Impact on the environment starts as design begins and materials are selected. As materials being used for building construction has to contribute to the emission of CO_2 and a loss of green space & deforestation disturbs the balance of nature. Knowing the impact of each material used will help identify which has the highest impact and use optional material with relatively less impact on the environment.

Different studies (Bengt Hjort, 2002) (Matsumoto, 2021) on housing especially low-cost housing (which is part of the mass housing system) have been undertaken in Addis Ababa. These studies have generally addressed the economic sustainability of mass housing with less emphasis on the social and environmental dimensions of sustainability. To address the challenges of housing in Addis Ababa, the analysis should be expanded to include all three dimensions of sustainability: economy, environment, and social dimensions. Therefore, this study is focused on evaluating the environmental impact of existing mass house schemes concerning GWP.

1.3 OBJECTIVE

1.3.1 GENERAL OBJECTIVE

The main objective of this research is to assess the environmental impact in terms of Global warming potential caused due to mass housing development in sunshine real estate.

1.3.2 SPECIFIC OBJECTIVES

- To Estimate embodied CO_2 of mass housing development up on the Environment.
- To identify points in the early design phase of mass housing development that ensures environmental sustainability.
- To recommend a decision support method for the early design phase of mass housing developments that reduce GWP.

1.4 RESEARCH QUESTION

The main questions this research is intended to find are as follows.

- What is the GWP of a mass housing project?
- How can architects reduce the environmental impact while designing new mass housing projects?
- What criteria are used to make decisions on the design stage of mass housing developments?

1.5 SIGNIFICANCE OF THE STUDY

Residential development often constitutes the major ratio of the built-environment. Hence, it is of paramount importance to be able to have correct decisions in the early phases of designing large-scale mass-housing projects. This study is vital to understand the effects of mass housing system on the environment. It will implies points to consider in selection of material in the design of mass housing. The study is based on the existing mass house scheme in Addis Ababa. It is going to evaluate the building by measures of environmental impact assessment on the building materials. The methodology used in this study can be used as support tool for planners to study the environmental impact in mass housing development.

1.6 SCOPE OF THE STUDY

Spatially the study is limited to a real estate development in Addis Ababa. A real estate development is a large scale design with similar typology buildings. It make sense to study impact of a lot of buildings under similar circumstance. Although there are a lot of real-estate developments in the city these days the study was focused on Sunshine real-estate at ‘Meri Luke’ and ‘Gerji’ site due to the access for the data required for the study. Also it has been about 17 years since the projects on real-estate began, and would be able to see the significant change throughout the years. In the real estate mass housing of residential units will be studied. The design phase of the residences are the main concerns from whole life cycle assessment for the study. The environmental impact studied in concern of the CO2 emission/global warming potential (GWP) construction materials in the designs will be studied. This element especially the materials of a building are categorized in the 1st stage of building life cycle (A1-A4) which are selected in the design stage of a building. This stage also defines the storey, built up area and typology of building designs, which are significant data for the comparison of the two sites (with apartment and villa) for the following study.

1.7 LIMITATION OF THE STUDY

This study has faced different challenges and has come to some limits that make it difficult to bring out the needed output. These challenges include the society knowledge about environmental sustainability, non-organized data about details of the residential buildings in the study area. As the guideline utilizes a reference LCA study in order to generate scenarios, & the framework is dependent on the available data collected in the study. The amount and quality of collected data have impacts on precision of environmental data of components and representativeness of the reference LCA study. This was the very big challenge because Sources of environmental data are third party groups such as manufacturers in most cases which were not fully available in this level of study.

1.8 ORGANIZATION OF THE PAPER

This paper is organized in five chapters. This first, containing the introduction, background, the Objectives, scope and the research questions, along with this description which Summarizes what follows in the remaining chapters. The second chapter consists of a literature review on mass housing, environmental sustainability, environmental impact, LCA and sustainable building design and related studies. The third chapter provides a thorough description of study material and methods used in both data collection and in its analysis. Here, the sample population which is selected from a real-estate are explained and the LCA methodology is put forward. The fourth chapter then explains the result of the study; including findings of sample project LCAs, together with a discussion of collected questioners' results from the population of the study area. The fifth chapter concludes the study by summarizing its findings and offering relevant recommendations.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 TERMS AND DEFINATION

Environmental impact: An environmental impact is defined as any change to the environment, whether adverse or beneficial, resulting from a facility's activities, products, or services. In other words, it is the effect that people's actions have on the environment. For example, when volatile organic compounds are released into the environment, the effect or impact is pollution in the form of smog, in this case being negative. (Ethan Boechler, 2021) In this study the term environmental impact refers to the impact caused due to a building structure.

Global warming potential: is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO_2. GWP is 1 for CO_2. It is taken as the gas of reference.

Mass housing: is defined as a dense and repetitive housing solutions that has emerged as a complement of urban regeneration projects to cover the acute shortage of housing especially in the big cities. (Nilüfer Saglar Onay, 2019)

Real estate: is a property consisting of land or buildings according to the definition in the dictionary. In this study it is considered as property consisting of buildings in a category of mass housing development.

2.2 THEORETICAL LITERATURE

2.2.1 MASS HOUSING DEVELOPMENT

The term mass housing was absorbed into architecture from the industrial sector to describe mass production methods of housing development projects (Ahadzie, 2007). In this regard, all tried meanings of mass housing draw on the physical qualities of the project such as size, nature of designs, and extent of properties involved. (Folaranmi, 2012) From these qualities, it is clearly obvious that the main underlining themes in most meanings of mass housing are "large unit production," "multiple site location," and "repeated schemes". (Folaranmi, 2012). From the medieval almshouses of Europe to the blocks of Pruitt-Igoe, mass housing has changed in function and texture. The motives for erecting housing estates have varied with time along with the political, social, and economical effects and their role in defining the urban fabric of modern cities. (Upadhyaya, 2021)

The structures of projects are major limitations and contributions for the right choice of management method and equipment for the conveyance of the project (Maas, 2008). It is, however, highlighted that every project shares its own features and these features require specific capabilities and talents from crews, groups, and corporations to efficiently manage and execute them (Maas, 2008). It can clearly be stated that the accepting of the nature and structures of projects is critical towards its actual management to assurance effective delivery (Kipp A, 2008)

The strategies of participants in housing production, in developing countries are diverse and not fully understood. Governments in most developing countries been able to, sufficiently, explore how the production factors: land, impact on housing production. As a result, many policies formulated aimed at stimulating housing production are found to result in unintended do not always align with the way housing. It is recommended that efficient land supply to the autonomous on-site be a focus for policy makers. This will contribute to the production thereby facilitating an improved production of present and future housing population. (Muyiwa Agunbiade, 2012)

Mass housing has a worldwide consequence on the environment such as energy depletion in the form of excess misuse of the normal assets for raw measureable recycled for the building constructions like wood, mineral resources such as gypsum, chipping, sand, stone among others. The recurrent usage of those assets mains to their over mistreatment in that way disturbing the environment which suggests energy usage foremost to worldwide warming affecting weather changes. In the same manner, mass housing development has caused to greenhouse gas release due to the usage of power producing tools at site like bulldozers, pay loaders and other heavy vehicles at site (Brebbia, 2002).

Though residential houses are considered by many as being beneficial for the health of the people, they have a dangerous environmental mark. The housing area is one of the maximum suppliers to the deprivation of the environment and the extreme global normal intake amount of energy, whether it be from electricity or from natural resources (Marshall, 2005)

2.2.2 ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability is the duty to preserve natural resources and defend worldwide ecologies to upkeep well-being and comfort, nowadays and in the forthcoming. Because so numerous choices that disturb the environment are not felt instantly, a crucial part of conservation sustainability is its progressive nature. (Team, 2020)

Environmental sustainability is the tolls of renewable resource yield, contamination, and non-renewable resource reduction (Morelli, 2013) and is the most vital for the existence of existing creatures (Díaz S, 2006). Human actions like industrial development, deforestation, and overexploitation of natural properties by showing population, depriving farming activities, and much more have controlled the environment to the edge of failure driving world nations to arms to stop further decline of the environment and reestablish its permanency (Hopwood, 2005); (Clark, 2014). Many methods like waste reprocessing and sewage handling systems have been tried to ease the condition but only met with little or no achievement. Agriculture, in the beginning, was an ecological action, but with the arrival of the green revolution, chemical fertilizers and insecticides conquered and enlarged its undesirable mark on the environment (Leo Horrigan, 2002).

Environmental sustainability plans comprise activities to decrease the usage of physical assets, the embracing of a ‘recycle everything/buy recycled’ method, the use of renewable somewhat than delectable capitals. The redesign of manufacture procedures and products to remove the making of deadly resources, and the defense and renovation of natural environments and surroundings valued for their livability or attractiveness (Sutton, 2004).

These sustainability plans need to function on a satisfactory gauge and essential to endure functioning dependably for as long as the intimidations last.

Some of the matters that stance main environmental sustainability difficulties include:

- demolition of the existing environments (habitats) of natural species
- release of contaminating chemicals and other resources into the environment
- release of greenhouses gases into the atmosphere that can reason climate alteration
- reduction of low-cost oil and additional fossil fuels (Sutton, 2004)

2.2.3 ENVIRONMENTAL DEGRADATION AND MASS HOUSING DEVELOPMENT

Several international organizations recognize environmental degradation as one of the major threats facing the planet, since humans have only been given one Earth to work with, and if the environment becomes irreparably compromised, it could mean the end of human existence. (Golland, 2004)

There are a number of ways in which environmental degradation can work. In a classic case, resources simply become depleted. Air, water, and soil are all resources which are vulnerable to depletion through overuse, as are natural resources like minerals and oil deposits. Habitat pressures which force animals into a small area can also contribute to resource depletion, as the animals consume a high volume of material in a small area. (Brundtland, 2007)

Pollution is another cause of environmental degradation. When the environment becomes polluted, it means that toxic substances have rendered it unhealthy. Pollution can come from a variety of sources, including vehicle emissions, agricultural runoff, accidental chemical release from factories, and poorly-managed harvesting of natural resources. In some cases, pollution may be reversible with costly environmental remediation measures, and in other instances, it may take decades or even centuries for the environment to cope with the pollution. (Vehbi, 2009)

Simple damage is also a common issue. Clear cutting, unsustainable development, and erosion are all forms of environmental damage. If the damage is extensive, the environment may not be able to reach a state of balance on its own, and the problem could become compounded. Erosion as a result of bad agricultural practices, for example, can strip the earth of its valuable topsoil, leaving coarse, useless soils behind. This infamously occurred in North America during the Dust Bowl of the 1930s, in which drought, poor farming practices, and severe weather led to a widespread stripping of fertile topsoil from farmlands. (Vehbi, 2009)

A number of social and legal issues are involved in environmental degradation, ranging from the need to provide living space for humans to questions about who is responsible for environmental cleanup. For example, if a company acquires a company which released toxic chemicals into the environment in an era when this practice was commonplace, it may argue that it has no legal obligation to clean up the chemicals, although it may be obliged to do so under ethical principles. (Brundtland, 2007)

The construction and use of modern buildings causes substantial environmental damage, creating about 50% of greenhouse gas emissions and considerable ecosystem degradation. In the United States, buildings account for 39 percent of total energy use, 12 percent of the total water consumption, 68 percent of total electricity consumption, and 38 percent of the carbon dioxide emissions (UNDP, 2011)

According to UNDP Washington Newsletter in 2011, the environmental damage from buildings arises across the whole life-cycle of buildings, which have a very wide range of environmental impacts and demands. The environmental damage can also be summarized as follows.

- Ecosystem and biodiversity loss and impacts from the global consumption of natural resources for building through the depletion of vital ecosystem services. Essentially a reduction in the environment's capacity to maintain our current lifestyle or to improve the lifestyle of the less disadvantaged
- Climate Change and impact of pollutant - from the greenhouse gas emissions and other pollutants associated with buildings

2.2.4 CHALLENGES REAL ESTATE DEVELOPMENTS IN RELATION TO ENVIRONMENT

The real estate development plays a great role in alleviating the housing problems in Ethiopia. There are many challenges associated with real estate development. The lack of proper policies, rules and regulations, requirement of high capital, land acquisition problems, scarcity of construction materials, price escalation of construction materials, foreign currency problem and devaluation of local currency, lack of long term financing, trust loss of buyers, political unrest and other problems are the major identified challenges. (Wendafrash, 2021)

Real estate development is a multi-step process that can be risky, lengthy and complicated. There are plenty of obstacles that can pop up along the way of real estate development. It can take years to bring a project from the initial planning stage through construction to final completion stage. Real estate development projects also can be highly lucrative investment opportunities (Smith, 2018)

2.2.5 ENVIRONMENTAL EVALUATION FRAME WORKS

There are several frameworks for environmental evaluation of built environment. Though LCA is commonly applied in most environmental evaluations Background information regarding other frameworks is also given below. (Nkambwe, 2003).

Driving Forces-Pressure-State-Impact-Response Framework (DPSIR)

The DPSIR (Driving Forces-Pressure-State-Impact-Response Framework) emphases on what has gone wrong with the environment and how to repair it. This framework is an addition of the Pressure-State-Response (PSR) model, developed by Anthony Friend in the 1970s, and afterward assumed by the Organization for Economic Cooperation and Development's (OECD) State of the Environment group. The framework may be distinct to address precise anxieties that may be of unusual awareness in a region or nation. In the situation of Africa, poverty mitigation and supportable livings have been recognized as the most significant (Nkambwe, 2003).

The Opportunities Framework

This method, as used in AEO-2, is mostly attentive on observing at possible chances for decreasing scarcity and stimulating ecological livelihoods. It beginning by making a record of current assets and observing at tendencies in the modern previous at the scale of interest (local, national, sub-regional or regional) and clarifying why the perceived trends have happened. While the DPSIR method is environment-pressures positioned, the Opportunities Framework emphases on the obtainable resources and how they can be sustainably recycled for social and economic growth. Opportunities could also be in the procedure of foresting a ruined forestry, for example. The present resource base in the environment offers an advantage that can be better with objectives to offer sustainable incomes (Nkambwe, 2003).

Life Cycle Assessment (LCA)

LCA studies the environmental aspect and potential impacts throughout a product's life from raw material acquisition through production, use and disposal. Life cycle based assessment is a new approach in environmental assessment of built environment. It is intended as a comprehensive approach and championed for integrating the strengths of LCA and bridging the inadequacies of rating systems. (Ragheb, 2011)

2.2.6 LIFE CYCLE ASSESSMENT OF BUILDING

The different periods of a building's life are known as its life-cycle stages. They are referred to as product, construction, use, end-of-life and benefits beyond the system boundary. The standardized module designations for each life-cycle stage, from A1 to D, is shown below in (FIG 3).

Definition: Building LCA is a science-based methodology for quantifying the lifetime environmental impacts of a building. The processes involved in the life-cycle stages of a building releasing gaseous, solid, and liquid emissions into the air, water, or soil can negatively impact the environment and humans. (Curran, 2015)

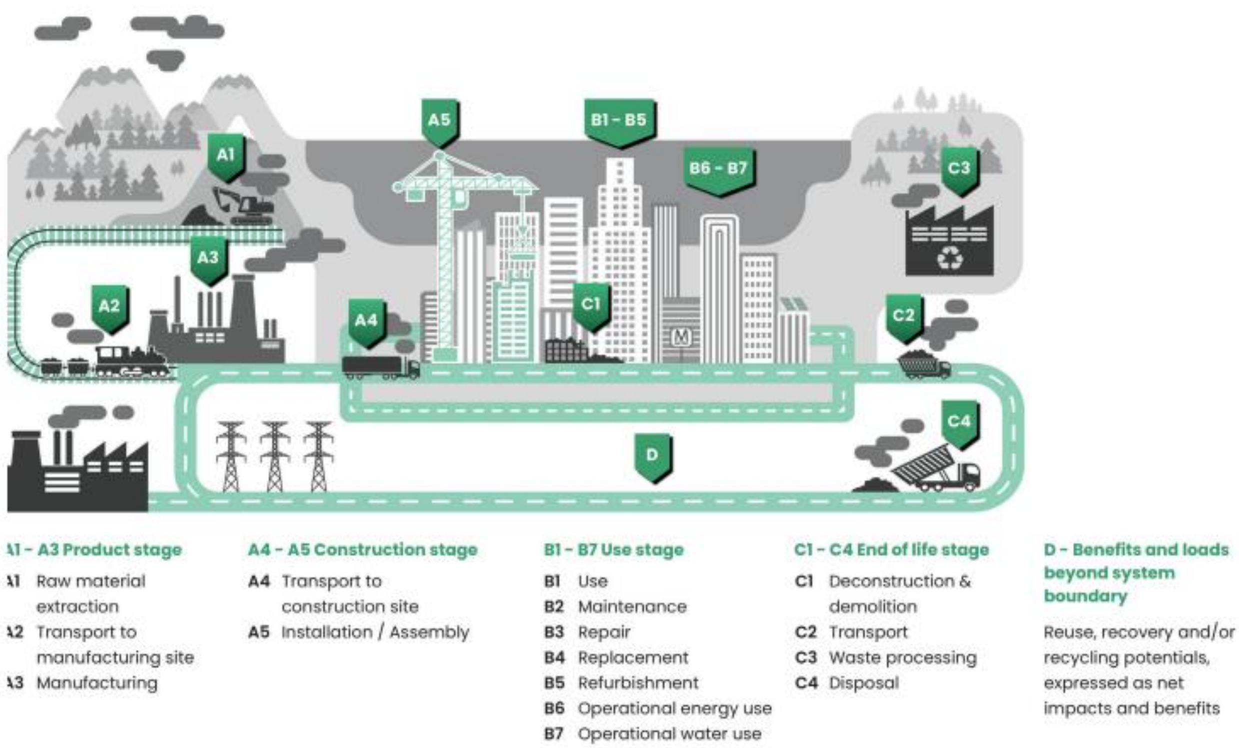

FIGURE 3 Life-cycle stages of a building

Purpose:

When conducting LCA at different stages has different purpose. It is very important to do LCA at early stage of design. It has advantages for designing a green building, very flexible for different design concepts and gives the ability to set target and make major choices that consider the environment. When LCA is done at the detailed stage of design it can used for comparison with design alternative and for carbon benchmarking. Another stage of building where LCA is conducted is at construction / on building usage. At this stage its only purpose is for certification and comply with regulations. (Curran, 2015)

LCA according to different standards:

The ISO 14000 product oriented standards include Environmental Labels and Declarations, Life Cycle Assessment and Eco design. These standards are intended to be used to assess and report on environmental performance of products and services, and to provide guidance on improving their environmental performance. The ISO 14040 series standards, Life Cycle Assessment, address quantitative assessment methods for the assessment of the environmental aspects of a product or service in its entire life cycle stages. ISO 14040 is an overarching standard encompassing all four phases of LCA. There are three more standards supplementing ISO 14040. ISO 14041 deals with goal and scope definition and life cycle inventory methods. ISO 14042 deals with life cycle impact assessment methods and ISO 14043 life cycle interpretation methods. (Lee, 2004)

For this research LCA method based on ISO 14040 guidelines is the tool used for environmental assessment. Since it is based on mass and energy balance method. And it also assesses buildings using a consistent framework. It measures all inputs to a building and all outputs that are released to the environment. (Lee, 2004)

There are many issues that must be considered before appraising claims that one or another building type or product offers a better environmental reappearance. To comprehend the full environmental effect of a structure over years of usage, all stages, starting before construction and continuing up to demolition, must be well thought-out. Life cycle assessment (LCA) pursues to enumerate the environmental effects over the arrangement of life cycle by recognizing the expenses during each phase (MIT-Team, 2017).

LCA can be used to gain recognitions in certification systems like LEED, but traditional LCA means can be time, resource, and data exhaustive. For composite methods like housing buildings, these strains can lead to late valuations with assessments conceded out next significant project choices have already been made, decreasing their value (MIT-Team, 2017).

The LCA method considers environmental impacts of a particular building component or system or the whole building, during its life-cycle. The expression 'life cycle of a building' refers to the manufacture of building materials, transport, construction of the building, occupancy/renovation, and finally demolition and removal. (BS, 2011)

2.2.7 SUSTAINABLE BUILDING DESIGN

According to U.S. National Institute of Building Science (WBDG, 2013) the main objectives of sustainable design are “to reduce, or completely avoid depletion of critical resources like energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure throughout their life cycle; and create built environments that are livable, comfortable, safe, and productive”.

Sustainable housing requires to be intended to make best use of occupants’ health and decrease the environmental burden. The search of merging these two unlike features near sustainability is a goal-oriented duty. The discipline of regulator can be practical to all goal-oriented jobs. Therefore, applying controlled discipline, we have been developing in research on sustainable housing project. Therefore, based on the recognized difficulties associated to housing, system designers recognize the necessities for sustainable housing design. (Fujihira, 2019)

The literature review has made an understanding of what type of data should be collected to do the life cycle assessment of the mass housing studied. There are some significant software related reviews omitted due to unstructured data. But those are as important in the whole process of calculating the environmental impact in the life cycle assessment tool.

2.2.8 PRINCIPLES OF ENVIRONMENTALLY SUSTAINABLE MASS HOUSING DEVELOPMENT

The principle of sustainable housing is to give comfort and safety in human lives. The application of this principle occurs directly and indirectly recognized by the owner or not. The principles applied in sustainable housing, including concern for people by ensuring that they live in a healthy, productive and in harmony with nature. (Nazirah, 2005)

There are six (6) principle of sustainable housing. This principle needs to give priority to the interests of future generations without compromising the needs of the present generation applied.

- Energy Efficiency

Increasing the use of energy by the optimum building orientation, sun minimize entry through building ventilation, natural lighting, adapt best practices in building services, including the use of renewable energy and regular maintenance.

- Internal Environmental Quality

Achieve good performance in indoor air quality, acoustics, visual and thermal comfort. This will involve the use of low volatile organic compounds, filtration applications in air quality, temperature control, conditioning and proper humidity.

- Site Planning and Management of Sustainable

Selecting a suitable site with access to public transport, community services, open space and landscaping. Conservation of environmentally sensitive areas through the development, implementation and management of a systematic construction, and reduce the pressure on infrastructure capacity.

- Materials and Resources

Choosing materials that are not environmentally friendly and have a negative impact on humans, flora and fauna. Sources used in preference to minimum and reusable materials.

- Water Efficiencies

Rainwater harvesting, water recycling and water system equipment.

- Innovation

Innovative designs ensure that architecture is constantly evolving functionally and aesthetically.

2.3 EMPIRICAL LITERATURE

2.3.1 SUMMARIZATION OF PREVIOUS STUDIES

Two similar studies are reviewed and summarized as follows. The first one is for a mass housing development in Nigeria and the other is likely similar study done in the context of Somali.

2.3.1.1 Mass housing development process in Lokogoma (Nigeria, district of Abuja Phase II.) and Federal Capacity Territory as a whole involves some activities categorized into the following: (MEDUGU, 2014)

Design Process: This stage involves the design of the land such as architectural drawings, mechanical and electrical drawings and infrastructural designs. After vetting of the drawings by the Development control department approvals will be given for development.

Site Clearance: This forms the first construction activities in mass housing construction process. It involves clearing of the wanted vegetation cover that may hinder the construction process, cutting and filling of wanted valleys and depression, extraction of the soil and blasting of unwanted rock outcrop.

Site Fencing: This involves demarcation of the plot where mass housing construction will take place. It involves the delivery of materials for fencing such as blocks, cement, chippings and sand. The delivery of these materials involves the use of Trucks, Lorries and Vans.

Infrastructural Development: It involves the construction of relevant infrastructure within the mass housing site such as construction of roads, drainages, walkways, waste sewers and bitumen surface.

These activities have been the normal practice in mass construction in the Federal Capacity Territory. However, the use of construction equipment has some negative impact to the immediate environment 8 especially impact on air, vegetation, soil, water and landforms. Therefore there is the need for environmental analysis to determine the effect of mass housing construction on these environmental components.

Mass housing development in Lokogoma district in the Federal Capacity Territory has resulted to the following Environmental problem;

1. Air pollution: The surrounding area has been contaminated with toxic components as a result of operation of heavy machineries and equipment in mass housing sites. Construction activities from site clearance to finishing has resulted to the generation of particulate matter, fumes and dust thereby affecting visibility and causing health hazards. The use of machineries especially drilling machine have contributed a lot of noise in the surrounding neighborhood thereby creating nuisance to people.

2. Deforestation: This is the major environmental problem of the district over the years as a lot of indigenous tree were cleared in the name of housing and infrastructural development.

3. Soil degradation: The housing development has result some forms of land pressures within Lokogoma district and has led to land pollution (open dumping of solid waste especially construction waste) soil erosion and some risks of desertification and drought especially behind GODAB and IPENT estates.

4. Flooding: The sand filling of natural drainages, stone peaching of stream channels and conversion of green areas for housing development within the study area has paved way of chances of flooding to occur as evident in some part of the estate was water logged in the raining season last year.

2.3.1.2 A review from the paper Sustainable solution for mass housing design in Africa describes the outcomes of a project, intending to propose sustainable solutions for mass-housing design for new sustainable settlements in Mogadishu.

The problem stated in the study is that rapid housing developments create an amplified carbon Footprint and further negative impacts on the environment. The building sector is one of the largest consumers of natural resources and energy since it uses 30–40% of all primary energy and natural resources over the building's lifespan (construction, operation, maintenance and demolition) and accounts for 30% of the global emission of greenhouse gases. (Del Pero, Bellini, Martire, & di Summa, 2021)

The designs of most contemporary buildings deny the inevitable interactions with the natural surroundings, and site characteristics such as orientation in the design process, and are subdued with expensive cooling and lighting equipment. Sites and their locations for example are important factors in relation to environmental design strategies and impact on the indoor conditions of a building. This makes knowledge of the physical surroundings as well as micro-climates useful in formulating passive building design solutions. The design of buildings that do not take physical surroundings and micro-climates into consideration are highly dependent on mechanical and electrical systems to control the indoor environment. In an era where the international community is advocating for application of sustainability building principles, the use of conventional mechanical systems to obtain comfort is now questioned in energy poverty economies like that of Ghana. In this way, application of passive design techniques should not only be seen as an environmental issue but also from an economic point of view.

The proposed methodology, applied in the context of Mogadishu, led to the definition of a concept design of a representative housing unit, which has been optimized from the energy, social and cost points of view. In detail, the specific assessment of the possible construction techniques and materials allowed to observe that innovative solutions like the proposed precast panels are more in line with the target of the sustainability, due to their massive reduction in terms of costs and to their improved eco-profile versus common concrete solutions and EPS panels. And the possibility of local industrialization of the construction techniques supports reducing the uncertainties of construction cost and timing while triggering new business ecosystems for sustainable settlements. The proposed solution meets several Sustainable Development Goals (SDGs), i.e. 3 (good health and wellbeing), 7 (affordable and clean energy), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities) and 13 (climate action).

From the above review we can conclude that the main problem is the buildings and those mass housing development, whose production process is complicated, and whose life span is long with future phases based on assumptions. Many Researches done to overcome the environmental impact. But the nature of the building industry makes it difficult to have an international dataset available for all users, due to the difference of each area climate, available materials and techniques of construction. Which can make the life-cycle assessment studies different. The credibility of LCA results for use in performance or informing and influencing design decisions will depend up on a number of factors such as data quality and uncertainty, assessment methodology and assumptions made. Although the limitations and criticisms presented in this paper are not adequate enough evaluation of environmental impacts of buildings LCA is considered comparable method. It has the potential to make a contribution to the goal of reducing environmental impact.

2.3.1.3 LCA Methodology Applied to Materials Management in a Brazilian Residential Construction Site

Location: Brazil

Type: Residential Unit

Area: 56m^2 Average

Structure: Concrete structure

This functional units of this LCA study has a living room, kitchen, utility area, bathroom, two bedrooms, garage, and a deep yard, with a total built area of around 56 m2 on average. The objective of the study is to analyze the environmental impacts of the selected functional unit using the LCA methodology to evidence and compare environmental impacts when using different construction materials.

Data Collection. Quantification of the materials was based, in general, on the 13th edition of Tables for Compositions of Prices for Budgets, which is considered one of the reliable databases in Brazilian building construction (TCPO, 2008).The amounts of each material can be observed in the table below. The inputs and outputs were based on the databases used in this work. The transportation model used for all construction phases is the road transportation, once this mode of transport is easy to reach and the area next to the site has a large road system connecting the country. In the manufacturing phase, the construction site is considered the same location for construction and extraction of raw materials.

Material	Quantity (kg)
Steel	5,034.37
Ceramics	131,798.13
Cement	28,369.30
Wood	
Parana Pine	5,853.76
Peroba-Rosa	4,197.82

Table 2 Quantities of materials

The Life Cycle Impact Assessment is conducted According to ISO 14040. (ISO, 2006) The assessment of impacts translates consumption and waste identified in the inventory phase environmental impacts, such as the greenhouse effect, hole in the ozone layer, smog, acid rain, eutrophication, and toxicity. To manage those elements, the method of calculation IMPACT2002+ was used. Further observation categories were those related to global warming, natural resource consumption, consumption of nonrenewable energy, and toxicity to human health.

Result:

The results presented were based on the comparison and analysis of the materials used in the functional unit of one family unit in the selected construction site of this study. In Figure 4, through the type of characterization, the translation of incoming and outgoing flows in the impact IMPACT2002+ method version 2.05 is presented. The most significant impacts are life cycles of steel, cement, and ceramics. In 2 of the 15 analyzed impact categories, carcinogens (toxicity to human health) and mineral extraction (consumption of nonrenewable energy), the life cycle of steel is almost exclusively characterized as the most significant agent.

Global warming and the use of nonrenewable energy, which are somewhat interconnected, have the life cycle of ceramics as the main agent. The non-carcinogen categories and ionizing radiation were those in which cement showed greater expressiveness. Steel, concrete, and ceramics are characterized as major causes by impacts. Applying the method of standardization by the IMPACT2002+ methodology, it is observed that the most significant impacts, taking into account all materials, are related to global warming. As shown in Figure 5, when applied to the single score, global warming has the most obvious impact on the life cycles of all materials considered, followed by the use of inorganic nonrenewable energy and breathing. The functional unit considered is one family unit in the selected construction site.

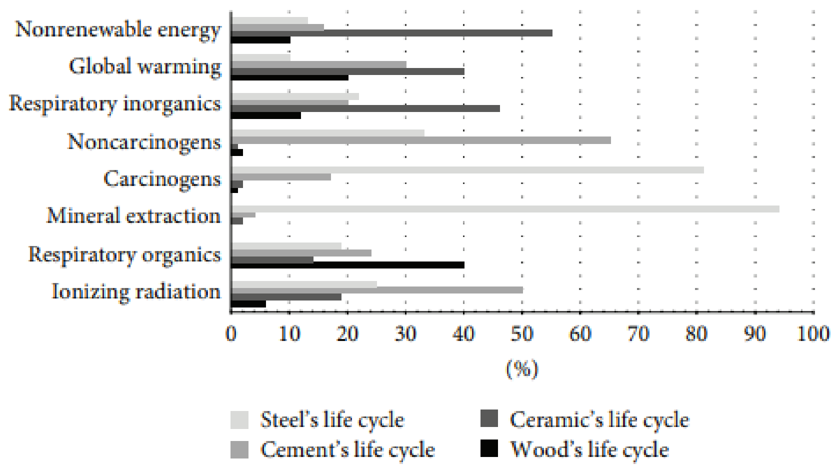

FIGURE 4 Comparison of the life cycles of selected materials, IMPACT2002+ method, and characterization

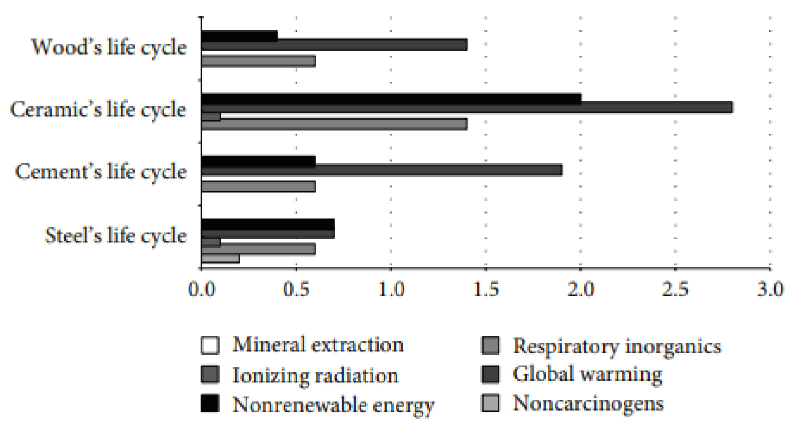

FIGURE 5 Comparison of the life cycles of selected materials, IMPACT2002+ method, and single score

Based on the analyzed data and results of those materials life cycle, the most severe impacts are related to global warming, consumption of nonrenewable energy, and toxicity to human health. This global warming impact is more representative by the life cycle of ceramics. Moreover, it is important to note that the ceramic material was in greater quantities, corresponding to about 75% by weight of the materials considered for the construction of the site studied, as shown in Figure 6, so this higher impact was expected. In the context of global warming, the life cycle of cement also stands out. This can be explained by the natural process of manufacture of clinker, called calcinations, that is responsible for significant emissions of carbon dioxide, which contributes significantly to global warming. Regarding toxicities, considering the effects of steel and cement effects in human health, the most significant impacts were cancer and respiratory inorganic substances. The former is, for the most part, from the life cycle of steel, and the latter is from the life cycle of pottery. Despite this high impact, steel and cement are key materials that are difficult to replace in the traditional system of construction, especially in Brazil.

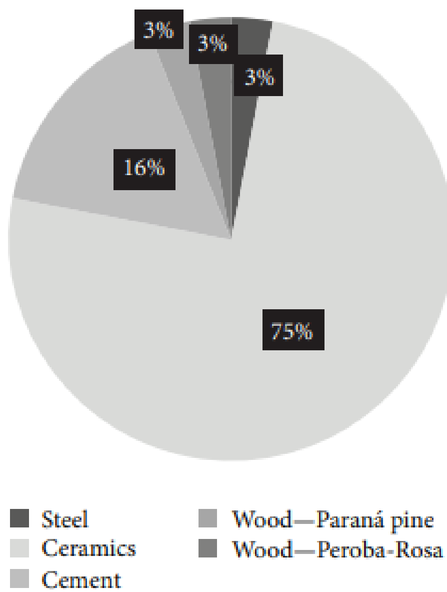

FIGURE 6 Composition of building materials (kg)

These case studies give a general idea on the overall challenges of a mass housing development. This studies are examples on how to implement the impact assessment challenge in case of the research's study area. As mentioned in the above sections addressing environmental issue (GWP) is the aim of this research. Previous studies in local has taken in accordance to the economical and societal challenges of a real estate development. This are mentioned in studies of Mekuria Haile about Urban Land Policy, Housing, and Real Estate Markets in Urban Ethiopia (2022), Milka Hagos in the study of Analysis of Risks in Residential Real Estate Development Projects of Addis Ababa (2016), and Factors Affecting the Real Estate Market the case of Addis Ababa City by Kiros Aqubamicheal (2009)

CHAPTER THREE

3. MATERIAL AND METHODS

This section describes the methods to be used in the conduct of the research. Description of study area, the type and source of data collected, the samples selection for data collection, and materials/instruments used for documentation and document finalization. It also includes the analysis of the collected data.

3.1. DESCRIPTION OF THE STUDY AREA

This study is conducted in one of the real-estate developments in Addis Ababa Ethiopia. Addis Ababa is located at 8.9806° N, 38.7578° E. The total area Of Addis Ababa is 527 km2 and average temperature of currently there are more than 5 million people. ¾ of the population live in overcrowded house or dilapidated structure. From 2000 to 2015, Addis Ababa's population grew by 37% (from 2.8 million to 3.8 million) and its built-up area by 32% (from 85km2 to 113km2). (Matsumoto, 2021)

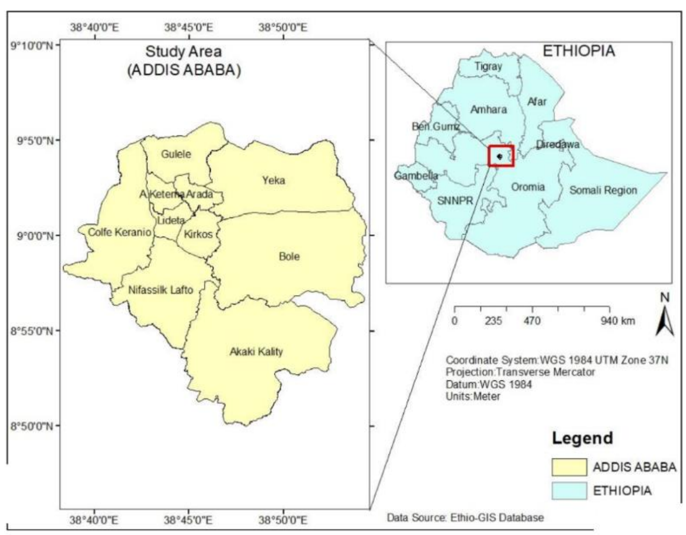

FIGURE 7 Location Map

3.2 RESEARCH DESIGN & APPROACH

This is study aims to show the impact of mass housing on the environment. It is a known issue that the building construction industry has impacted our surrounding in many different ways. Studying the effect can be valid when similar buildings in same site are considered. And this study describes those effects of the environment in one specific thread which is GWP. Therefore it follows both the ontology philosophy and epistemology philosophy of a research. And an abductive approach was conducted with the use of qualitative and quantitative data.

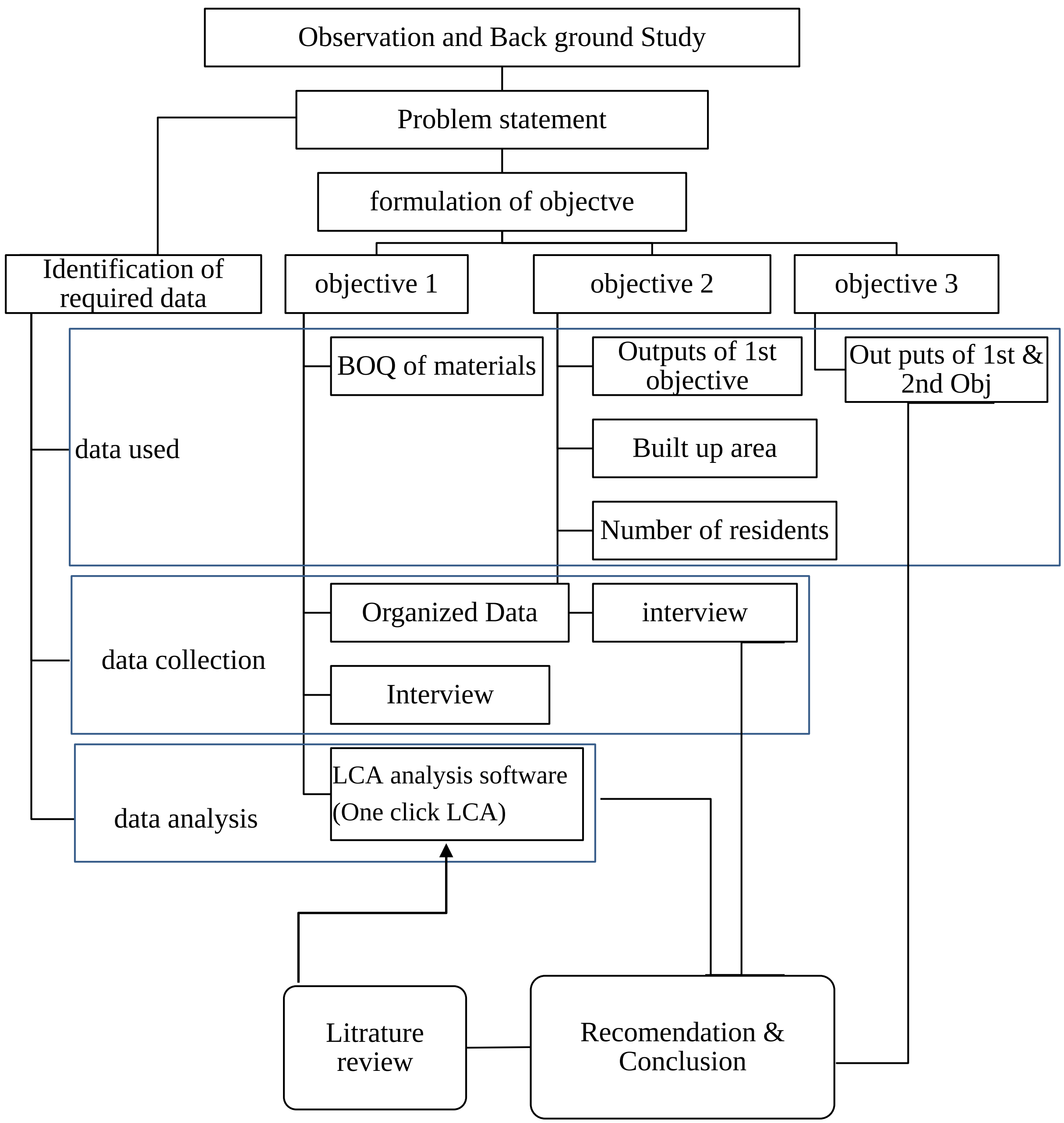

FIGURE 8 Research Design

3.3. TYPE AND SOURCES OF DATA

Qualitative and Quantitative data were used for these research. The questionnaires were organized in a form both quantitative and qualitative data can be obtained. They are primary data from residents of real-estate & workers at the Plc. Those are responses of the questionnaires about number of house hold, occurred maintenance and others can be seen in chapter four section 2. Literature review and materials collected from the BOQ of company's documents are considered as secondary data of the research.

3.4 SAMPLE SIZE AND SAMPLING TECHNIQUES

According to data from Ethiopian Investment Commission, since 2015, close to 117 companies took an investment license to invest on different real estate projects. Sunshine was selected by random sampling from the oldest ones. Then sample population is defined as mass-housing projects of a Sunshine real estate developer company. Sunshine Construction Plc. was founded in 1984, as a sole proprietorship and later in 1993 transformed into a private limited company. According to sunshine construction plc. There are four sites were a mass housing development has taken place in these real-estate developer company. These are Meri-luke, gerji, cmc and bole beshale. The first two are completed, and the other two CMC and bole beshale sites are under construction. From the four sites meri luke is the site that occupies only single residential villas and the other sites include apartment complex. The percentage of the residential typologies are given on the table below.

No	**Site**	**Area (m^2)**	**type**	**Quantity**	**No of residents**
1	Meri Luke	124,368	Villa	210	210
			Gym, Hospital		
2	Gerji	28,760	Villa	15	15
			Apartment	33	547
			Shop	37	37
3	CMC no. 2	138,500	Apartment	114	2094
			KG and commercial building		
4	Bole Beshale	100,000	Villa	202	202
			Apartment	29	596

Table 3 Sunshine construction real estate projects 1997-now

As the data to be collected from the buildings were Qualitative a purposive sampling technique was used. The criteria was to include two type of residences built in a real estate projects. Single unit residential and apartment building. And also having an existing resident. From the four sites of the real estate two were selected which can be representative the criteria. The Meri-Luke compound and the Gerji site. And from those two sites a building with highest quantity is selected (villa typology B & Apartment typology D). After selection of the site important information were asked in interviews from those who are thought to have the required data. Those are the construction office workers and of sunshine real-estate PLC.

No	Typology	Area (m^2)	Storey	Quantity	Built up area(m^2)
1	A	500	G+2	1	120
2		250	G+2	45	110
3	B	500	G+2	66	120
4	C	500	G+2	1	120
5		250	G+1	6	110
6	D	500	G+2	57	120
7		250	G+1	3	90
8	E	250	G+1	31	114

Table 4 data chart of sunshine real estate Meri Luke site

No	Type	Typology	Storey	Quantity	Area(m^2)
1	Villa	A	G+2	5	
2		E	G+1	10	
3	Apartment	A	G+4	3	480
4		B	G+4	2	162.21
5		C	G+4	-	159.4
6		D	G+4	25	326.56
7		E	G+4	2	383.15
8		F	G+4	1	274.35

Table 5 data chart of sunshine real estate Gerji site

For the study of existing buildings residents and committees of the resident units were interviewed and questionnaires were revealed. The method for selecting sample were randomly from the residential of the area because of the reason that most of the owners are not available to chat with. From the 210 residents of Meri Luke 66 are in the selected residential typology and from those 10 were interviewed. And 20 people from total of 442 Apartment typology D residents of Gerji site.

Architectural drawings and interviews with responsible staff (Architect, construction manager etc.) were utilized for necessary data. This staff members are selected based on the information they provide. The first step was to go to sunshine construction Plc. which is the owner of sunshine real estates in the study areas. And the responsible staff for design of this residential villas are MH engineering.

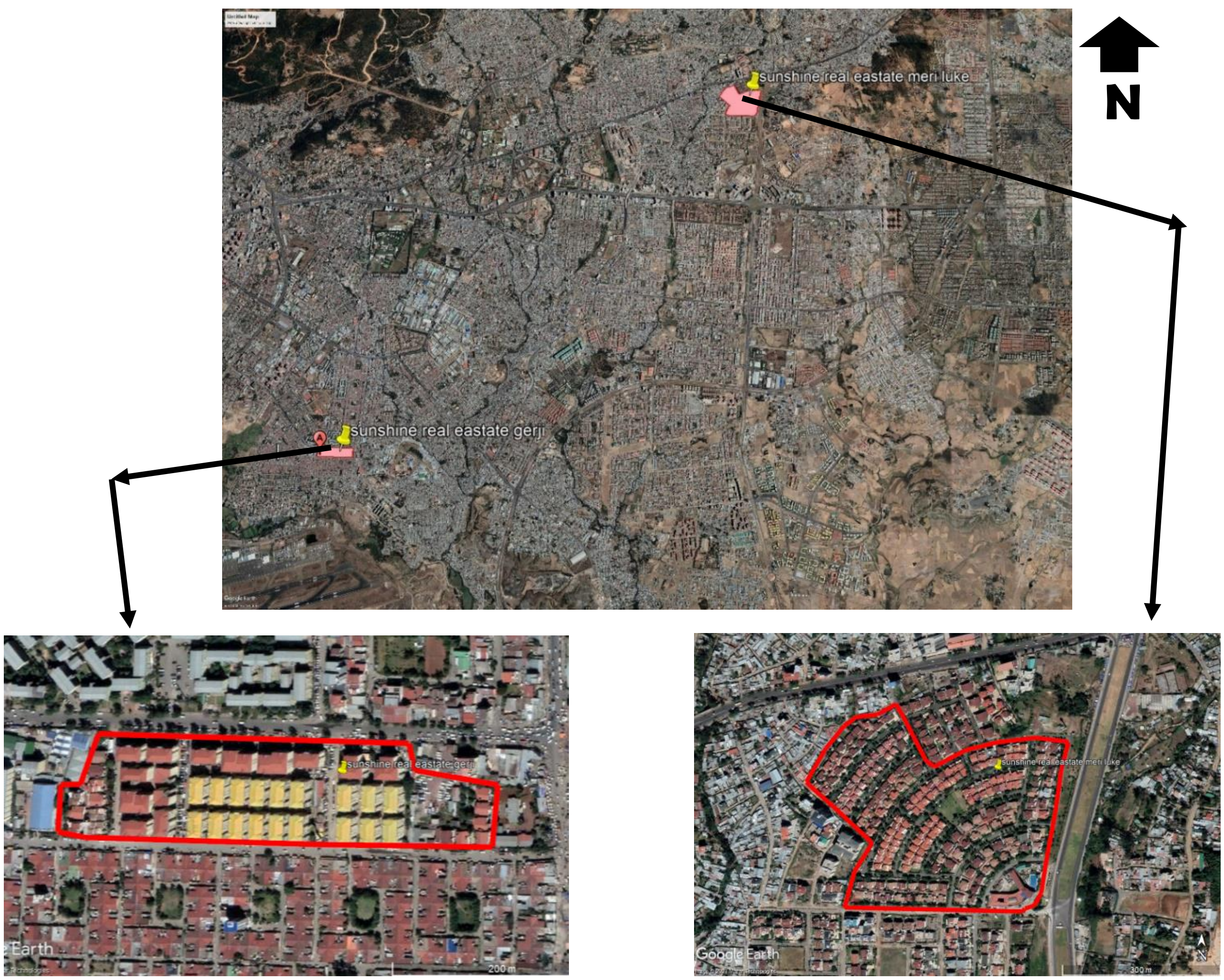

FIGURE 9 Study areas location map

3.5. DATA COLLECTION TECHNIQUES

Different methods were used for the collation of data. It includes observation, semi-structured interviews, questionnaires, and secondary data observation about the study area sites. For the observation a check list were prepared based on literature reviews.

3.5.1. SEMI STRUCTURED INTERVIEWS

After the collection of data in digital format (.dwg) and excel of the BOQ semi structured interviews were conducted with the construction company managers in order to compare with the data collected from the project documents with the actual realized construction. The interview was focused on data that were not mentioned on the drawing & BOQ as like where material come from & history of the area.

3.5.2 QUESTIONNAIRES

There were two types of questionnaires prepared. The first one includes personal details of residents that contain questions like number of families, duration in the buildings. And other relevant things about the building (changed materials, painting) are included in both the first and second questioner prepared for the residences committee.

3.6. APPLICATION OF LCA

3.6.1. DEFINITION OF THE GOAL AND SCOPE

Life cycle assessment is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials. (Ilgin & Gupta, 2010) The aim is to document and improve the overall environmental profile of the product. (Matthews, 2014)

The goal and scope of a LCA in this study is to form scenarios depending on the identified parameters for each cluster. The parameters are identified which are suitable for pre-design and schematic design phases.

3.6.2. FUNCTION OF THE SYSTEM AND FUNCTIONAL UNIT

A functional unit describes a quantity of a product or product system on the basis of the performance it delivers in its end-use application. Functional units are foundational to LCA, as they enable objective comparisons across different products or systems that serve the same final function. In One Click LCA product level calculations, the unit can be (without restrictions) selected based on the material, and the studied life cycle stage. For buildings, most of the LCA tools in One Click LCA provide results as an overall for the whole building and per 1 m2 of building area (different area definitions can be used). Furthermore, other units such as impacts per 1 m2 of building/year of building use or impacts per user amount might be offered for some tools.

3.6.3. SYSTEM BOUNDARIES

In this study the boundaries include the mass-housing projects of sunshine real-estate and consider only the building foot print and construction material with transportation to of the materials to the site. This materials include Concrete, HCB, Steel reinforcement bar, Timber, Gypsum boards, Steel studs, Roof cover clay tiles, precoated EGA, Steel frame work, Metal work, wood, glass, Acoustic ceiling tiles, Gypsum plaster, Ceramic tile, Plastic tile, Cement screed, Paint, Precast concrete pavement, and Marble.

3.6.4. IMPACT ASSESSMENT CATEGORIES

Impacts considered in a Life Cycle Impact Assessment include climate change/global warming potential , ozone depletion, eutrophication, acidification, human toxicity (cancer and non-cancer related) respiratory inorganics, ionizing radiation, Eco toxicity, photochemical ozone formation, land use, and resource depletion. From Standard impact categories listed the software used in this study supports all. But only Global warming potential (GWP) were considered to be studied. The global warming potential is calculated in carbon dioxide equivalents meaning that the greenhouse potential of emission is given in relation to CO2. The unit is given as KgCO2-eq (A carbon dioxide equivalent) since the residence time of gases in the atmosphere is incorporated into the calculation, a time range for the assessment is defined to be 60 years.

3.6.5. LIFE CYCLE ENVIRONMENTAL IMPACT ASSESSMENT (LCIA)

Impact assessment is performed according to the building types given in previous section. Assessment methodology for each building is given as Component, classification and as a whole building. For all three clusters environmental impact assessment was done in scope of embodied carbon and GWP. Details of analyzing the Impact assessment are given in the section below.

3.7 DATA ANALYSIS METHOD

The collected data were analyzed by LCA software. All available data were entered to the database and an outcome was generated. The evaluations are guided by the literatures reviewed. During the evaluation process observed points were included as a remark.

In the calculations, all the different emissions from evaluated life cycle stages are collected and normalized to a common unit. In the case of Global warming potential, the reference is the warming potential of CO2 emissions e.g. how much heat 1 kg of CO2 will tie into the atmosphere. The warming potential of all the other cases is compared to the CO2 and based on that the quantities are normalized to the common unit. For instance, the warming potential of methane is 24 times higher than CO2 so 1 kg of methane emissions will be 24 kg of CO2equivalents. Impact assessment methodology defines the relative weight of different emissions and the normalization unit.

Below are steps for LCA assessment in One Click LCA.

The first step was to create a new design Then Fill in the building materials query of the design Using average data, manufacturer-specific EPDs (recommended) or similar products from another manufacturer. Net quantities (amounts of material installed in the building) were used. This information is used to calculate the raw material harvesting, transportation and manufacturing impacts in A1-A3

Once the correct materials and quantities were provided, the transportation distances were set from material manufacturer to the project site and transport methods. Then check the material service life. This information is used to calculate the material replacements for B4 impacts. Material service life means how long each material will last in your building. If the service life is less than the service life of the building, the material will have to be replaced. From an environmental impacts point of view, this means additional emissions from the production of new material that is needed to replace the old one.

The next step was Adjusting the localization of each material as needed & Fill in the building area. Then finally fill in the calculation period query. LEED recommends a service life of at least 60 years. Product replacements and maintenance are calculated for this period.

The results of this study is compared with a similar work that is conducted upon the case studies. And the comparison will be performed with similar studies in other countries. The quantitative data will be analyzed through charts and figures. Then finally the outcomes gathered from the checklist and interview will be guided with the current EPA policy in Ethiopia and early design stage guide lines will be reviewed to make a recommendation.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. EXISTING CONDITION OF THE SELECTED SITES

4.1.1. STUDY AREA 1: MERI LUKE SITE

The Meri Luke site is where the first study has taken place. It is Located: 9°1'57"N 38°51'1"E. the site includes 210 residential units with a playground and a gymnasium and a hospital are also provided along with the residential compound. It is the oldest and the site that consists of all villas. It is located at a distance shown below from different parts of the city.

- Kotebe 3.8 km
- Koye Fache Condominium sites 13 km
- Gefersa (West) 27 km
- SUMMIT 2.5 km
- Legetafo 3 km
- Yeka Abado Condominium Site 4.5 km
- AYAT Condominium 5.1 km
- Left Base Sewerage 6.5 km
- Bole Arabsa Condominiums 8 km
- Wedecha-Dam reservoir lake 19 km

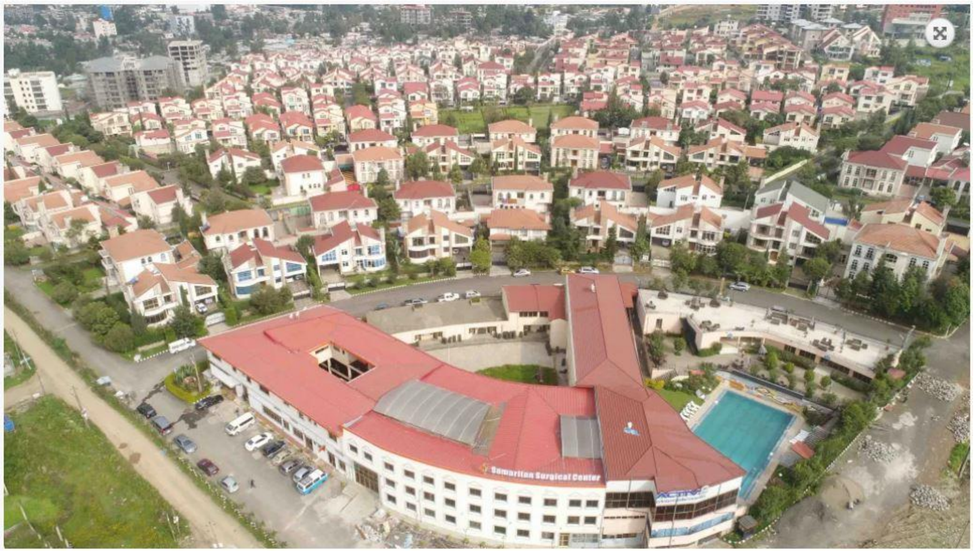

FIGURE 10 site photo of Meri Luke sunshine real estates

FIGURE 11 Meri-Luke Villa Typology B Floor Plan

The table below shows the BOQ of Meri Luke residence typology B arranged in a format to be used in the analysis software. Similar materials in different section are added up together and materials. The analysis main categories are class of the material, specification of materials, quantity, quantity measurement type and thickness where it is available.

CLASS	IFCMATERIAL	QUANTITY	QTY_TYPE
FOUNDATION	Reinforced Concrete - C-25	112.5	M3
	Gravel	0	M3
EXTERNAL WALL	Ready-mix concrete C25/30	0	M3
	HCB 20cm thick	235	M2
SLAB	Hollow-core slab, 250 mm	72	M2
	Leveling screed	0	KG
COLUMN	Steel reinforcement bar	3933	KG
OTHER	Timber	112	M2
INTERNAL WALL	Gypsum boards, 12,5 mm	0	M2
	HCB 15cm thick	111	M2
	Steel studs for 400 mm spacing	0	M2
ROOF	Roof cover clay tiles	153	M2
	precoated EGA 500	0	M2
STAIRS	Ready-mix concrete C25/30	3	M3
	Steel frame work	27	M2
DOOR	Metal work	52.81	M2
	Internal door, wood	21.63	M2
WINDOW	4mm thick clear glass	58	M2
COVERING	Acoustic ceiling tiles	0	M2
FINISH	Gypsum plaster	850	M2
	Plaster	850	M2
	Ceramic tile	117	M2
	Plastic tile	133	M2
	Cement screed	133	M2
	Paint	868	M2
SITE	Precast concrete pavement	55.3	M2
	Marble	5	M2

Table 6 list of materials for the Villa B Meri-Luke site

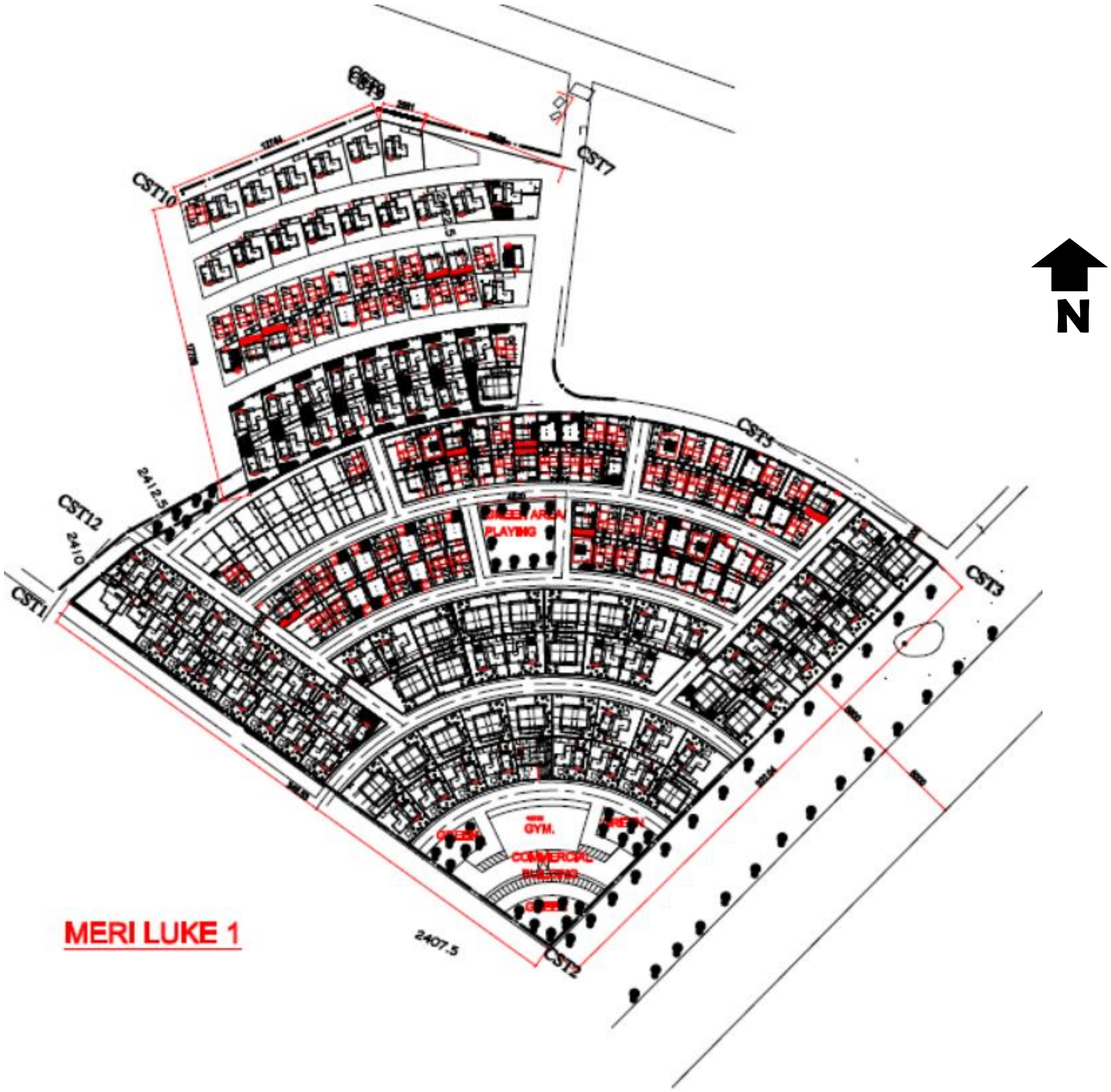

FIGURE 12 Meri Luke site layout

4.1.2 STUDY AREA 2: GERJI SITE

Gerji is another site were sunshine construction completed and handed over to the residents. Construction begun by the year 1998EC and given to residents in 2002EC. So it has been 12 years since the area has been occupied. The total area of the site is 28,760m^2. It includes 33 apartments and 15 villas. The type of villas are typology A and Typology E as built in the Meri Luke site. There are a total of 562 both in the apartments and Villa. And in addition 37 shop are built on the ground floor of the Apartments.

FIGURE 13 Gerji Apartments

The table below (table 7) shows the residences typology, number of story, quantity and plot area of the buildings. For the apartment each type of BHK per floor is also included.

Typology	**No of families/ floor**	**No of BHK**	**Quantity**
A	3	3BHK	1
		2 BHK	2
B	2	1 BHK	1
		2 BHK	1
C	-	-	-
D	4	Studio	1
		1 BHK	1
		2 BHK	2
E	3	2 BHK	3
F	2	2 BHK	2

Table 7 data chart of Apartments sunshine real estate Gerji site

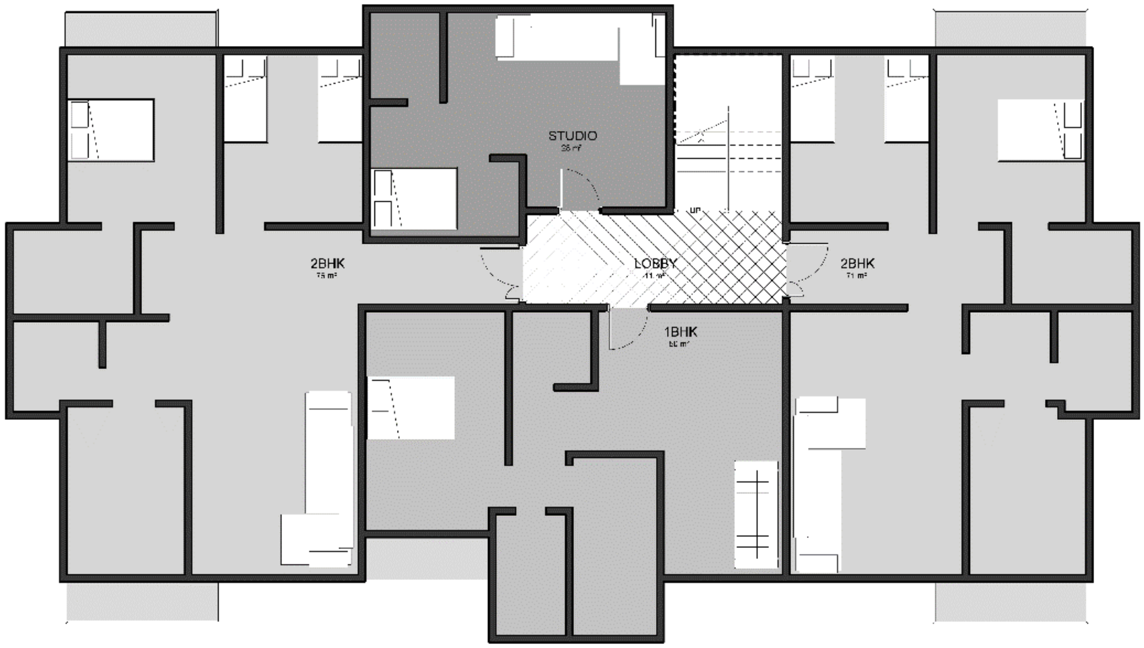

FIGURE 14 Gerji Apartment D Typical Floor Plan

The table below (table 8) shows the BOQ of Gerji Apartment arranged in a format to be used in the analysis software. Similar materials in different section are added up together and materials. The analysis main categories are class of the material, specification of materials, quantity, quantity measurement type and thickness where it is available.

CLASS	IFCMATERIAL	QUANTITY	QTY_TYPE	THICKNESS_MM
FOUNDATION	Reinforced Concrete - C-25	147.72	M3	
	Gravel	2.34	M3	
EXTERNAL WALL	Ready-mix concrete C25/30	6.72	M3	
	HCB	1365.23	M2	
SLAB	Ready-mix concrete C25/30	10	M3	
	Hollow-core slab, 250 mm	25	M3	
	Leveling screed	10	KG	
COLUMN	Steel reinforcement bar	64460.6	KG	
OTHER	Timber	2358.36	M2	
INTERNAL WALL	Gypsum boards, 12,5 mm	170	M2	12.5
	Steel studs for 400 mm spacing	170	M2	
	HCB	1065.48	M2	
ROOF	Precoated EGA 500	399.16	M2	4
STAIR	Ready-mix concrete C25/30	14	M3	
	Reinforcement steel	1600	KG	

DOOR	Metal work, Aluminum profile	598.95	M2	
	Internal door, wood	217.17	M2	
WINDOW	4mm thick clear glass	327	M2	
COVERING	Acoustic ceiling tiles	90	M2	20
FINISH	Gypsum plaster	4432.58	M2	
	Plaster	7472.2	M2	
	Ceramic tile	582.66	M2	10
	Plastic tile	888.35	M2	2
	Granite			
	Cement screed	888.35	M2	48
	Paint	5947.04	M2	
SITE	Asphalt, AB	17	M3	
	Gravel	50	M3	

Table 8 list of materials for the Apartment D of Gerji site

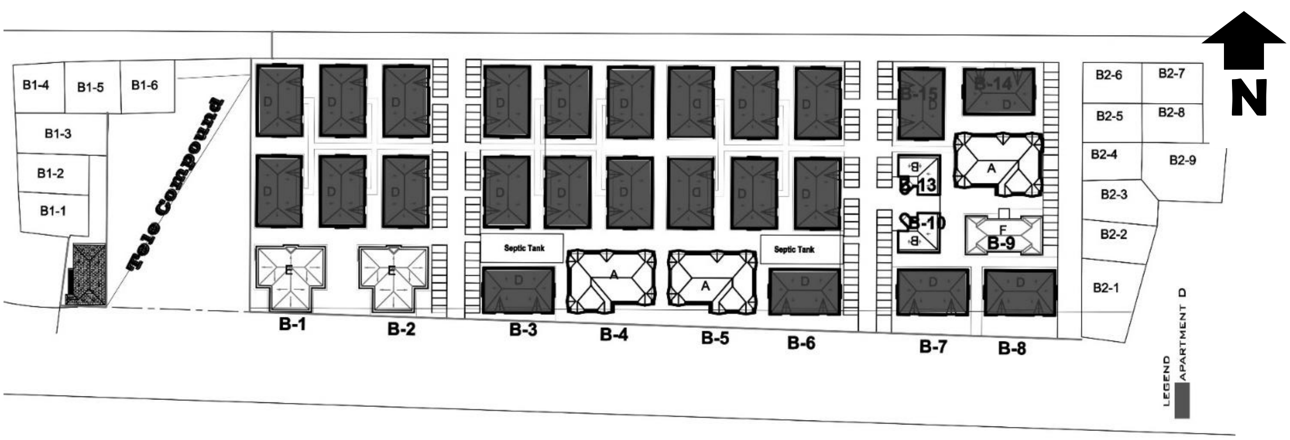

FIGURE 15 Gerji site layout

4.2 QUESTIONARY RESULTS

1. Duration of living

13 out of the 30 residents who participated in the questioner has lived in the housed more than 8 years. Out of the 9 residents who lived below 5 years in sunshine real-estate are from Gerji site apartments.

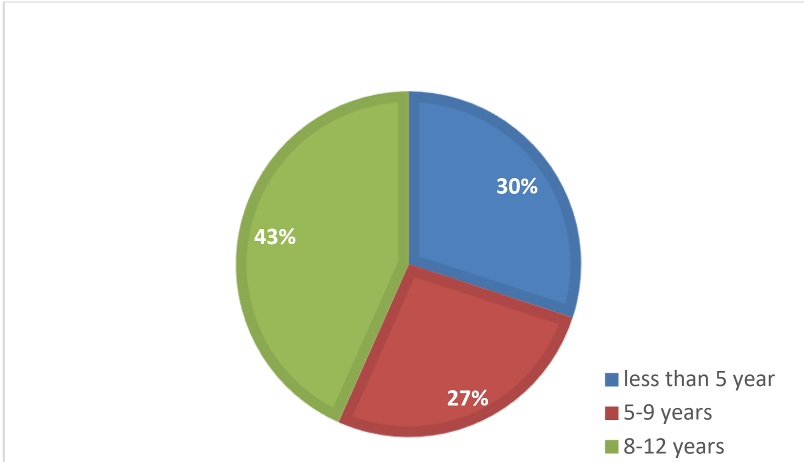

FIGURE 16 Duration of living at sunshine real estates

2. Number of families in one residence

The number of family members in every house was different. And it was necessary to ask this question in order to observe the land usage of the areas. And it is found that 60% of the units occupy more than four people living together. From this number above 70% are from Meri Luke single resident houses.

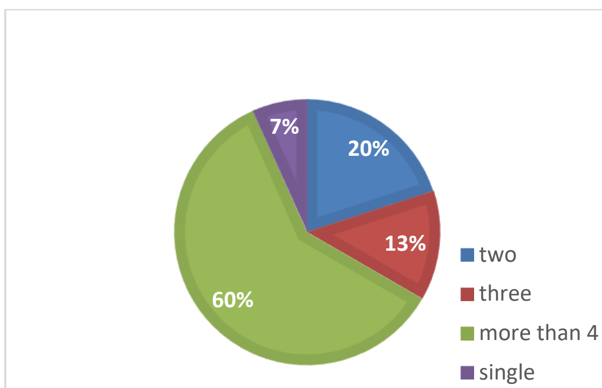

FIGURE 17 Number of people in one unit

3. Type of residence were sample populations live in

As the residents were asked randomly they live in different typology houses. Though the study area is focused on two specific typologies from the residents only 75% were from villa B and Apartment type D. the rest were from other typologies.

4. Changes made in the residences

Every resident has painted over the interior walls of the house after few years of moving in. except for those who moved in recently (below 2 years). Other changes on the exterior painting, materials of doors and windows and partition were also made. The ratio of the changes made are shown in the chart below.

Although according to the information from the residence village committees about 90% of the interiors are repainted.

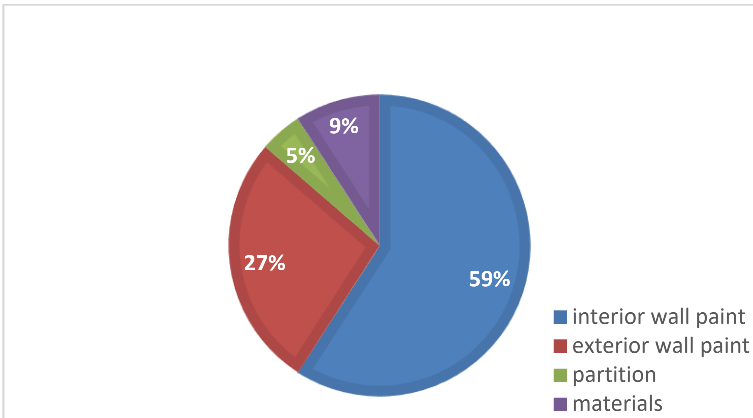

FIGURE 18 Changes made in the occupied residences

5. Other general responds

The answer was ‘No’ for the question about water heating system in the pipes was the answer of all the residents in both site of the residences. And the green areas get the required care frequently.

Pre design studies have a great role in meeting the demand of the population with the supply. As the results of the semi-structures indicated there were neither predesign studies taken nor EIA studies that occurred on the site. As both the real estate office and Architectural consulting firm confirmed the project was done the urgent need of housing in the city and government provided the land for built up of the residences. BOQ was done only for the cost analysis. The impact analysis was not considered in this phase.

4.3. ENVIRONMENTAL IMPACT OF MASS HOUSING DEVELOPMENT

4.3.1. EMBODIED CARBON OF BUILDING MATERIALS

This are findings of the 1st objective. GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2).

The Residence typology B form Meri-Luke site & Apartment Typology ’D’ from Gerji site were selected Buildings in the sample projects that were evaluated. Because as seen from the above data these are the most built buildings in those area. 66 & 25 respectively. The environmental impacts of following components were evaluated in the scope of cluster:

- embodied carbon of building during early phase (A1-A4)

  A1 Raw material supply

  A2 Transportation

  A3 Manufacturing

  A4 transportation to building Site

Analysis on embodied carbon on the two mass-housing projects according to CML-2001, GWP category was conducted. CML is a procedure used to estimate the measure of environmental impact that is caused by product. Focus of the analysis was construction phase which includes A1-A4 life cycle stages. Results were prepared in two levels:

- component,
- building

GWP values in kgCO2-eq for total and per m_2 on these two levels were calculated. Statistical analysis on project and component level was conducted. Results were also compared with related databases to ensure overall validity.

Component Level

Categorization of the building components have been prepared by adopting the Uniformat classification system. A list of components for detailed analyses was prepared according to the bill of quantities of each project. The building components which had low embodied carbon per unit and low quantity in project were omitted as their effect to the overall results were considered as insignificant. The embodied carbon of each component were calculated on per kilogram basis (kgCO2-eq/kg). For the analyses of the components, one click LCA software (online platform) was utilized with process and generic data. Also, environmental product declarations (EPD) were preferred for components without available process data. For components without process data and EPD, average of EPD values for similar building components were adopted. The results of analyses of LCA on per kg basis for both buildings in each building component can be seen in Figure 19. And the percentage for component classifications and resource type are included in Table 9, 10, 11, 12

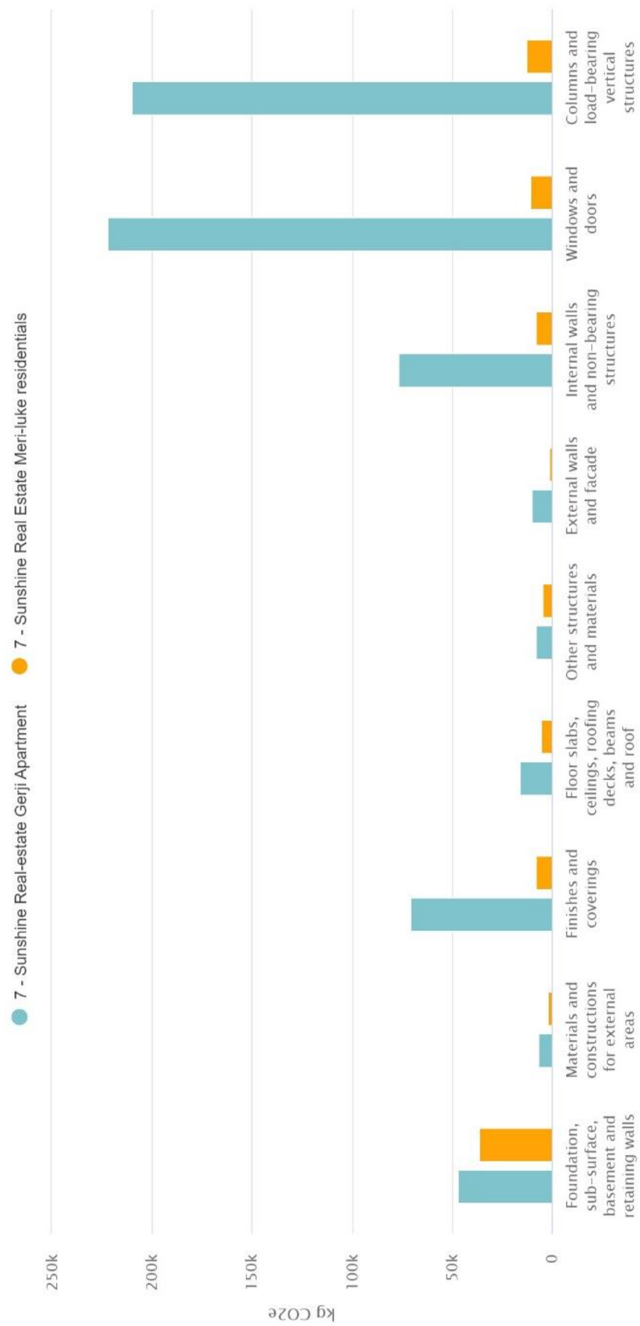

FIGURE 19 Embodied carbon of building components

In the above Figure (Figure 19) the results of embodied carbon of each component per kg was compared with in the two buildings. It was seen that large difference is observed in window and door s and vertical structures. This is due to the embodies carbon energy of concrete is high and the quantity required for G+4 Apartment building if far more than a single G+2 residential building. Below are the out puts of GWP by each component classification.

Item	Value	Unit	Percentage %
Windows and doors	220,000	Kg CO_2e	33.26%
Columns and load-bearing vertical structures	210,000	Kg CO_2e	31.48%
Internal walls and non-bearing structures	77,000	Kg CO_2e	11.51%
Finishes and Coverings	70,000	Kg CO_2e	10.54%
Foundation, Sub-surface, Basement and retaining walls	47,000	Kg CO_2e	7.1%
Floor slabs, ceilings, roofing decks, beams and roof	16,000	Kg CO_2e	2.41%
External walls and façade	10,000	Kg CO_2e	1.56%
Other structures and materials	7,800	Kg CO_2e	1.17%
Materials and constructions for external areas	6,500	Kg CO_2e	0.98%

Table 9 Gerji site global warming Kg CO2e by classification

Item	Value	Unit	Percentage %
Structural steel	220,000	Kg CO_2e	32.69%
Aluminum windows	220,000	Kg CO_2e	32.24%
Concrete slabs	85,000	Kg CO_2e	12.67%
Concrete structures	47,000	Kg CO_2e	7.09%
Gypsum board	38,000	Kg CO_2e	5.7%
Tiles	14,000	Kg CO_2e	2.07%
Screed	10,000	Kg CO_2e	1.56%
CMU	8,900	Kg CO_2e	1.33%
Play wood	6,800	Kg CO_2e	1.01%
Other resource types	24,000	Kg CO_2e	3.63%

Table 10 Gerji global warming Kg CO2e by resource type

The above tables 9 & 10 show the global warming potential Kg CO_2e of typology D of Gerji residence. It output is placed as a whole component and as material. As component windows and doors has the highest percentage by taking the 33.26%. While external walls & façade has the lowest percentage which is 1.56%. As seen from the second table of about the materials global warming potential is directly proportional. It can be seen that the component windows & doors are highest as of the aluminum window in the material section is 2nd highest with 0.45% difference from structural steel. This states the in case of building an Apartment the Doors and windows aluminum frame has high scale of polluting the environment by realizing tons of CO2.

Item	Value	Unit	Percentage %
Windows and doors	11,000	Kg CO_2e	12.32%
Columns and load-bearing vertical structures	13,000	Kg CO_2e	14.45%
Internal walls and non-bearing structures	79,000	Kg CO_2e	8.92%
Finishes and Coverings	8,000	Kg CO_2e	9.02%
Foundation, Sub-surface, Basement and retaining walls	36,000	Kg CO_2e	40.63%
Floor slabs, ceilings, roofing decks, beams and roof	51,000	Kg CO_2e	5.77%
External walls and façade	15,000	Kg CO_2e	1.72%
Other structures and materials	4,700	Kg CO_2e	5.24%
Materials and constructions for external areas	1,700	Kg CO_2e	1.94%

Table 11 Meri-Luke site global warming Kg CO2e by classification

Item	Value	Unit	Percentage %
Structural steel	13,000	Kg CO_2e	14.45%
Aluminum windows	14,000	Kg CO_2e	15.96%
Concrete slabs	9,500	Kg CO_2e	10.72%
Concrete structures	36,000	Kg CO_2e	40.63%
Gypsum board	5,400	Kg CO_2e	6.04%
Screed	1,600	Kg CO_2e	1.76%
CMU	1,500	Kg CO_2e	1.72%
Bricks	4,100	Kg CO_2e	4.6%
Concrete products	1,300	Kg CO_2e	1.49%
Other resource types	24,000	Kg CO_2e	2.64%

Table 12 Meri-Luke global warming Kg CO2e by resource type

The above tables 11 & 12 show the global warming potential Kg CO_2e of typology B of Meri Luke residence. It output is placed as a whole component and as material. As component

Foundation, Sub-surface, Basement and retaining walls has the highest percentage by taking the 40.63%. While external walls & façade has the lowest percentage which is 1.72%. As seen from the second table of about the materials global warming potential is directly proportional. It can be seen that the component foundation, basement and retaining wall are highest as of the concrete in the material section is highest. This states the concrete used for has high scale of polluting the environment by realizing tons of CO2.

Building Level

The following LCA or EPD standards are all fully compliant with the requirements of ISO 14044: ISO 14025, ISO 21930, EN15804. Assessment period fixed to 60 years.

A. sunshine real estate Gerji

Section	Result category	Global warming kg CO_2e	Acidification kg SO_2e	Eutrophication kg PO_4e	Depletion of nonrenewable energy MJ
A1-A3	Construction Materials	6.41E5	2.54E3	4.16E2	8.15E6
A4	Transportation to site	5.23E3	2.27E1	4.94E0	1.43E5
B3	Repair				
B4-B5	Material replacement & refurbishment	1.57E4	7.27E1	1.44E1	3.8E5
C1-C4	End of life	6.31E3	2.92E1	6.29E0	1.79E5
Total		**6.69E5**	**2.67E3**	**4.42E2**	**8.85E6**

B. Villa B, sunshine real estate Meri-Luke

Section	Result category	Global warming kg CO_2e	Acidification kg SO_2e	Eutrophication kg PO_4e	Depletion of nonrenewable energy MJ
A1-A3	Construction Materials	8.63E4	2.73E2	6.11E1	9.74E5
A4	Transportation to site	1.35E3	6.2E0	1.35E0	3.83E4
B3	Repair				
B4-B5	Material replacement & refurbishment				
C1-C4	End of life	1.3E3	5.95E0	1.29E0	3.73E4
Total		**8.89E4**	**2.85E2**	**6.37E1**	**1.05E6**

Table 13 Whole-building Life Cycle Assessment ISO 14040 & ISO 14044 (CML 2002; November 2012)

In the result of the Apartments of the Gerji site 669 Tons of CO2e is the total carbon dioxide equivalent emission from one single building of Apartment D calculated in years of 60 year use. And 409.5 kg CO2e / m2 is the emission divided by the total floor area. And the result of the Meri-Luke site 89 Tons of CO2e is the total carbon dioxide equivalent emission from one single building of villa B calculated in years of 60-year use. 370 kg CO2e / m2 is the emission divided by the total floor area.

As seen from the case studies above Brazil construction (2.2.1.3) the material that has the most contribution to global warming are ceramic and cement. And here in this study concrete structures which are based on cement have higher GWP. It can be observed that in both countries cases cement has been considered to have an impact on the environment. Although In the study of Brazil's functional unit, the quantity of the ceramic used is higher too.

In the case study (2.2.1.1) Mass housing development process in Lokogoma the environmental impact outputs are generalized as Flooding, Deforestation, Air pollution, and soil degradation Which are the causes (deforestation, Air pollution) and results (Flooding, soil degradation) of global warming. In both reviewed studies and this paper Global warming is considered the main environmental impact caused by the building sector.

4.3.2 LAND USE CONTRIBUTION ON GWP

At the early design stage of mass housing development land use is a key element. It also plays a great role that making critical changes in the environment. The second objective of this research is compatible here. Land use ratio is done in the first early design stage, along with the population. The results shown in the above section are for one single building only. And since this is a study of mass housing the calculated results are converted to the whole buildings in the site for the specified typology.

In the case of Meri Luke site, villa typology B has 66 units which are for 66 residents, with a total plot area of 7,920m2. And in Gerji site Apartment typology D has 25 blocks which are for 500 residents. (5 storey x 4 resident/floor =for a single building) with a total plot area of 8,164m^2.

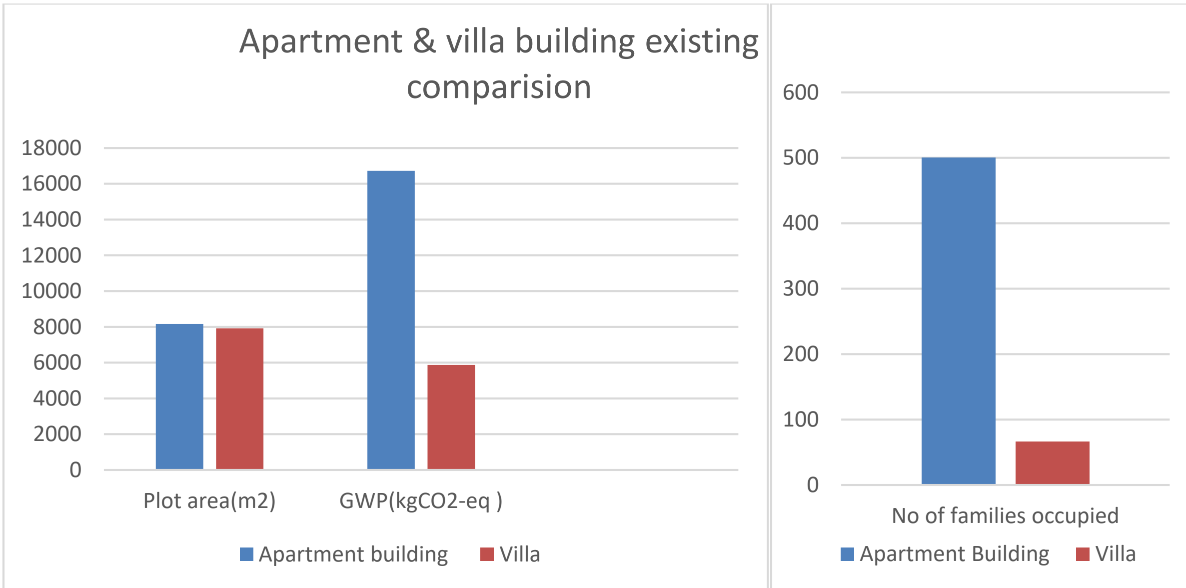

FIGURE 20 Comparison of Apartment Building with Villa based on plot area, GWP & Number of families occupied

From the above graph (FIG 20) it is observed that almost for the same amount of plot area the GWP is very far different. This is because the Apartment building has more storey than the single-resident building. Which means more structural elements (slab, beam, and column) and other elements. But on the side graph, it is observed the amount of residents these buildings occupy is quite different. There to have an equivalent comparison the number of residents was made similar.

BUILDING TYPE	APARTMENT	VILLA
An existing scenario of the study area		
Built up Area	326.56m^2	120m^2
Number of Storey	5	2
Total units	20	1
Total Floor Area	1632.8 m^2	240 m^2
GWP/60yr	409kg CO2e/ m^2	370 kg CO2e/ m^2
Modified for Land use calculation for similar floor area per unit		
Built up area	326.56m^2	840 m^2
Number of Storey	5	2
Total units	7	7
Total Floor Area	1632.8 m^2	1680 m^2

Table 14 Summary of selected building typologies in the Study area

The above table shows Land use ratio for the same single units in the apartment and villa. The single apartment building with a total floor area of 1632.8 m^2 can have approximately 7 units with a single unit area of 240 m^2 (which is the total floor area of 2 storey villa). To be compatible and compare the land use the villa was multiplied by 7 similar units. The result has shown that the built-up area for the villa is 2.6 times higher than a single apartment building.

4.3.3 DECISION SUPPORT METHOD FOR EARLY DESIGN STAGE OF MASS HOUSING DEVELOPMENT

For an effective design of mass housing, decisions should be made based on the basics of sustainability. This research covered environmental sustainability through a study of GWP as one of the impacts on the environment. These decisions include the population, land use, and embodied CO_2 of materials used. All three should be assessed carefully to study the GWP of mass housing. One method that can be used to assess CO_2 is LCA. An LCA study on the early design stage will be useful in the reduction of GWP in the following ways.

- To observe the impact of different design options
- To use alternative materials with lower GWP

Using this LCA study as base different design options that collide with the definitions of mass housing can be tested. As said mass housing is built to solve housing problems for the population. In this study, two types of residential buildings on mass housing scale are studied. Apartment Building and Villa housing. In terms of population, the apartment building seems to address a larger population with a lower built-up area relative to a single-unit villa. In a comparison of GWP, the villa has a lower GWP/ m^2 than the apartment. This is observed in Table 14. And below there is a comparison of the same number of residents in the apartment building and villa building.

FIGURE 21 Comparison of Apartments & Villa for the same number of occupants

As seen above the apartment building is already made for 500 residents, so only the villa was multiplied to occupy 500 residents. And results were 500 buildings with a total built-up area of 60,000m^2 and a total of 44,500 Tons CO2e is the total carbon dioxide equivalent emission from all buildings of the villa calculated in years of 60-year use**.**

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study is put forward to provide GWP of mass housing developments. Based on the GWP calculation using 'one-click LCA' software it was revealed that any building with a concrete structure affects the environment. But in comparison apartment buildings has potentially less impact on the environment than villa buildings for the same amount of residents. In general, Decisions regarding the planning of large-scale developments do have a significant effect on the environmental impact due to the large area and long lifetime they have.

After a study in one real-estate Company of two different sites, the following summary is given

- In the analysis of the environmental impact of residential buildings, it can be concluded that 99.9% of buildings in Addis Ababa are built in concrete structures. As being one of those building the residential of most real estate including sunshine, where the study is conducted, has used a concrete structure building. And from the above data observed and analyzed more than 40% of GWP is responsible by concrete. This is due to the transportation of raw materials for concrete and the production of cement that emits a high amount of CO_2 into the surrounding atmosphere. Although other materials have a crucial impact on the environment.
- Decisions on the early design phase of mass housing development are essential for the environmental sustainability of the site. Environmental sustainability on site can be measured in different mechanisms. From those land use and materials used is one to mention. Those being said the base of the design is the site analysis and pre-design studies. On the site where the study was conducted both the real estate company and the consulting office have confirmed that there were no studies conducted before design. An EIA was not conducted.
- This study has shown that an early design study of the LCA of a building is important to reduce its impact on the environment. It has shown that mass housing is considered for solving the housing problems of society. And in a way of doing those studies will help for better land use with a higher rate of occupancy/ addressing the population & reduction of GWP.

5.2 RECOMMENDATION

When one is planning to build/ design a mass housing development one should be aware of the drastic change that will be addressed to the environment. And accountability is not just for one building, it is in mass buildings, which might be neighborhood scale for this consideration.

Addressing the environmental impact of buildings at the early design stage provides the right timing for making major decisions regarding the material and lifelong aspects of buildings. During this study, it was seen that there was a lack of research on the environmental assessment of large-scale developments. Following that Real estate projects were focused and a decision support guide was developed. With the use of the guide (methodology used to do analysis), the environmental impact assessment procedure for mass-housing projects in Addis Ababa can be improved by application in the early design phase and inclusion of estimation of carbon emissions. The main findings of this study are summarized as follows:

- It is shown that transparency of data sources may be a great asset and tool for Strengthening the credibility of LCA studies and it can facilitate a better comparison And adoption medium for input and output data.
- In a way of addressing a large population a small built-up area with multi-storey provision has a lower environmental impact in comparison.

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Appendices

Questioner for residents in Gerji and Meri Luke compound Sunshine Real estates

By receiving this questioner it is believed that you are a resident in Sunshine real Estate

1. When did you move to the house you are in now(sunshine residences)

   Less than 5 years   5-8 years   8-12 years

2. How many people live in the house with you?

   ____

3. Which type of house do you live in? ___________
4. Have you made any changes to the house since you moved in

   Yes   No

5. If yes what were those changes?

   Paint   Partition   Exterior (façade materials)

   Cabinets   Doors and windows

6. how many cars is owned in your family.(house you live in)

   None   one   two   more

7. how far is your house from (put on the average Km)

   School __________   Work____________

   Family/relative/friends_________   Shop/market____________

   Any café or recreation area you usually go to__________

8. Does the pipes have water heating system?

   Yes   No

9. What system is used?

   Solar system   electric   none

10. Do you use any artificial ventilation

Questioner for Committees of Gerji and Meri Luke compound Sunshine Real estates

By receiving this questioner it is believed that you are a part of committee in Sunshine real Estate

1. Any changes/maintenance made in the houses?

   Yes ☐ No ☐

2. If yes how many houses have gone through any maintenance?

   ____

3. What are the maintenances on?

   Paint ☐

   Partition ☐

   Exterior (façade materials) ☐

   Cabinets ☐

   Doors and windows ☐

4. Is there any central generator system?

   ____

5. How many of the residences are rental or owned (for purpose of knowing renewal of painting of the house)

   Rental ________

   Owned________

6. Is there any sequential maintenance for the green areas?

   Yes ☐ No ☐

Interview with the real estate developers

General Information

1. Please confirm the number of dwellings and project area that are provided by the real-estate development
2. Details of the residential dwellings / typologies of residential.
3. Total area of the residential compounds, and surrounding landscape
4. What type of materials are used on the residential

5. In the material list give the percentage of produced by the company and imported from somewhere else

HVAC

6. What is the percentage of mechanic and electrical installations to the project overall?
7. What is the energy source for heating in the projects of real-estate development?
8. Is heating system individual or central?

Water consumption

9. How is domestic hot water being heated?
10. Is there any water treatment system?

Landscape

11. What is the percentage of landscaping works to the project overall?
12. How is water and electricity for landscaping being provided?
13. Are there any current studies for mass-transportation for this project?

Energy

14. Are there any renewable energy sources in the project?