University of Cape Town

ECONOMIC ASSESSMENT OF ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS IN MOZAMBIQUE: CASE STUDY OF MAPUTO

A thesis submitted to the Faculty of Engineering & the Built Environment in partial fulfillment for the award of the degree of

Master of Philosophy in Energy and Development Studies

by

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Declaration

I, Adélia Filosa Francisco Chicombo, hereby declare that this thesis is my own work, both in concept and execution, except where stated otherwise. This thesis is being submitted to partially fulfill the requirements for the degree of Master of Philosophy in Energy and Development Studies at the University of Cape Town. It has not been submitted for a degree or examination at this University or at any other University.

Signature:

Dedication

I dedicate this thesis to my beloved late father, Francisco Filipe Chicombo, who was always there for me.

Acknowledgements

Many people have contributed directly and indirectly for the success of this thesis, and I am thankful to all of them. Above all I am thankful to God, for enlightening and guiding me through my whole life. I am also grateful for all my family, especially my mother, for the encouragement during my studies.

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Abbreviations and acronyms

AC	Air Conditioning
BREEM	Building Research Establishment Environmental Assessment Method
CFL	Compact Fluorescent Lights
CMM	Conselho Municipal de Maputo
CNELEC	Conselho Nacional de Energia
CO_2	Carbon dioxide
CO_2eq.	Carbon dioxide equivalent
DOE	Department of Energy
DSM	Demand Side Management
EDM	Electricidade de Moçambique
EJ	Exajoules
EPBD	Energy Performance of Buildings Directive
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gases
GW	Giggawatt
HCB	Hidroeléctrica de Cahora Bassa
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
INE	Instituto Nacional de Estatística
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
Ktoe	Kilo tonnes of oil equivalent
kWh	Kilowatts Hour
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LEED	Leadership in Energy and Environmental Designs
LPG	Liquefied Petroleum Gas

m^2	Meter square
MOZAL	Mozambique Aluminium Smelter
MT	Meticais
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
Tcf	Trillion Cubic Feet
TPES	Total Primary Energy Supply
UE	European Union
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United State of America
W	Watts

Abstract

The world's energy consumption has been increasing dramatically in recent years. Economic and population growth are said to be the main drivers of this phenomenon. This change is held responsible for the increase in greenhouse gas emissions into the atmosphere, the reduced energy security and the negative socio-economic implications, especially in developing countries. From a sectorial perspective, buildings are part of the large energy consumers, especially the residential sector. It is in this view that measures to reduce this sector's energy demand has been largely recommended. One of these measures is promoting the deployment of energy efficient buildings combined with the use of energy efficient appliances.

The aim of this study was to assess the economic feasibility associated with sustainable buildings with emphasis on the energy efficiency component. The study concentrated on residential buildings in Maputo, the capital city of Mozambique. The rationale behind the study lies in the need to uncover the main variables involved in the economic feasibility of adopting energy efficient practices within the building sector to help final users, policy makers and other interested groups to better understand and handle energy efficiency matters.

A case study research design was used to achieve the main objective of this investigation. In this regard, a survey of households and interviews were conducted to establish the energy consumption pattern in Mozambique and its associated costs. The survey was conducted in the *Kampfumo* Municipality District of Maputo, and the interviews were conducted with civil engineering companies, electronic engineering, architects and building cost estimators. The questionnaires were answered by 233 households. Findings from the survey were used to perform a comparative analysis of the life cycle cost (LCC) of the buildings of the surveyed households with that of the proposed energy efficient designs, which incorporates buildings energy efficient elements and energy efficient appliances. .

Under the current circumstances, around 70 and 73% of the LCC of the houses occurs during the building operational phase, for type 2 and type 3 houses, respectively. It was found that all appliances that are currently being used by the households are relatively inefficient and could be improved by 50%, which resulted in significant reduction of the building's energy consumption, accounting for 56% and 68% for the type 2 house and type 3 houses respectively.

The main conclusion of this thesis is that, in Mozambique, the implementation of energy efficient measures in the type 2 and type 3 houses increases the building's LCC, except when the building envelope energy efficient measures are implemented in type 3 houses without taking into account the suggested energy efficient improvements to the household appliances. The finding was that under these circumstances, the LCC of type 3 houses is about 5% lower than that of its equivalent that does take into account any energy efficient strategies. The reduction of the LCC makes them attractive from the economic feasibility point of view. On the other hand, in case of type 2, the LCC was of about 1.5% higher when compared to that which does not incorporate energy efficient strategies.

Key words: *Energy efficiency; residential buildings; energy efficient appliances; energy efficient buildings; life cycle cost.*

Chapter 1: Introduction

This chapter provides the scope of the study. It contextualizes the study and discusses the main reasons underpinning the choice of the research topic, indicates the main objectives of the study, the limitations that were encountered while conducting the research and also discusses the importance of the research. Chapter two discusses the state of the art of previous work done relating to the scope of study.

1.1. Global context

It was in the 1970s when the world faced for the first time the oil embargo challenge together with high inflation rates in most commodities including energy. Since then, the world levels of energy consumption have been one of the central points of debate and analysis, and resulted in a massive adoption of energy efficiency policies worldwide, especially in the United States of America (USA) and European Union (EU). These debates and analyses usually fall under aspects such as:

a) **Energy security:** it is unquestionable that energy demand has been increasing dramatically since the industrial revolution. This increase worsens the security of energy systems regarding fuel availability, accessibility affordability as well as acceptability (Kruyt *et al.*, 2009).

b) **Environmental implications:** the increase of the greenhouse gases in the atmosphere is indicated to have severe negative implications in the climate system, which is contributing for example to global warming, climate change, air pollution and the depletion of ozone layer.

c) **Social and economic impacts:** energy is a scarce commodity in many countries especially in low income countries, usually with prohibitive prices that are constantly increasing due to its high demand levels (Ryan and Campbell, 2012).

The first steps to address these issues were made by the USA and the United Nations (UN). In 1969 the USA promulgated two acts, namely: the National Environmental Policy Act, and the Coal Mine Health and Safety, and in 1972 during the conference of the UN in Stockholm, it was indicated that the importance of addressing environmental problems that affects both rich and poor countries (Schipper and Meyers, 1992).

Despite these efforts, energy is still being consumed in an inefficient manner not only in developing countries but also in developed economies, which presents an opportunity to introduce improvements. The building sector is not an exception; it also presents a wide array for improvements. The building sector alone consumes a great deal of energy worldwide making this sector extremely important in the pursuit for improvements in the rational and efficient use of energy at local and international levels. The International Energy Agency concurs with this, and estimates that the primary energy consumed by this sector surpasses the figure of 40% (IEA, 2013a).

Population and economic growth are the main factors that contribute towards the increase of energy consumption worldwide. Furthermore, the projections indicate that these two factors will continue increasing in the years to come, which means that there will also be an upward trend in the consumption of energy.

Fossil fuels, which are finite sources of energy, represent the main source of energy that the world depends on. The global increase in energy consumption exacerbates the dependence on these fuels, and also diminishes the level of energy security. In addition, this increase has also been indicated to have severe negative socio-economic and environmental implications. Climate change, depletion of the ozone layer and the increase in air pollution are considered to be some of the adverse impacts caused by the increase in energy consumption.

Studies conducted by the IEA (2013b) and Intergovernmental Panel on Climate Change (IPCC, 2013), indicate that the negative implications resulting from the changes in the climate systems are already being felt in all nations regardless of their developing stage, and because of the lack of mitigations capacity, developing countries, such as Mozambique, have an aggravated risk of suffering the most from the consequences of the increase in energy consumption.

This situation then raises concerns about how the humanity will keep balance between the upward trend of energy consumption and the dependence on resources that are scarce and mostly unsustainable. Throughout the world, different institutions and organization have been designing, promoting, financing and implementing policies that contribute toward the reduction of energy consumption as well as the dependence on fossil fuels.

In this perspective, in 2012 the United Nations General Assembly launched a global initiative named “Sustainable Energy for All”, which among others, indicates energy efficiency to be one of the pillars that could contribute toward the reduction of energy demand (REN21, 2013). For that, this institution has set a goal for all nations to contribute in doubling the rate of improvement in energy efficiency. Energy efficiency can be implemented in different sectors of any economy, including but not limited to transport, industry, non-residential and residential sectors and each of them is required to contribute toward reducing energy consumption. Hence, the building sector is indicated to be the largest final energy consumer (Rebitzer *et al.*, 2004; IEA, 2010; Sharma *et al*., 2011).

Pérez-Lombard *et al.* (2007) indicates that in developed countries, buildings are held responsible for 20% to 40% of the global final energy consumption, and in accordance with this, Pérez-Lombard *et al.* (2011) states that, all across the world building sector is responsible for about 33% of the total primary energy consumption. A more recent study conducted by the IEA indicates that, currently buildings account for 40% of global final energy consumption (IEA, 2013a). Moreover, according to this source the residential sector represents the bulk of this figure, accounting for 23% of the global consumption. Therefore, this research will focus on the building sector, particularly the residential building sector in Mozambique.

1.2. Mozambican context

Mozambique is a developing country located in Southern Africa. Figure 1.1 depicts Mozambique location in African Continent. The country ratified the Kyoto protocol from the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. The main goal of this convention is to stabilize the greenhouse gases (GHG) concentration in the atmosphere at levels that prevents anthropogenic interferences in the climatic system. As per the convention rules, non-annex I countries such as Mozambique have no legally binding commitment to reduce its GHG (Fay *et al.,* 2012). Nevertheless, as a responsible member of the global community the country is called to make a contribution towards curbing climate change, since it affects all society regardless of their development stages.

Mozambique has insignificant levels of GHG emissions when compared to developed countries. In fact, even when compared to other developing countries such as South Africa, Zimbabwe, Brazil and India the country still falls under these countries in terms of GHG emissions. Factors such as services based economy, lower population density and poverty influence the economy to have such minor GHG emissions. The country relies mainly on hydropower for electricity generation and also consumes large amount of fire wood to supply most of the rural and *peri* urban areas needs of energy. Nonetheless, implementing measures such as energy efficiency in the residential sector may impact positively not only by increasing the country energy security but also towards achieving the global goal of curbing climate change.

Figure 1.1: Mozambique's Location in African Continent.

The residential sector in Mozambique is responsible for consuming the bulk of the total final energy. It accounted for over 70% of the total final consumption in 2011 (IEA, 2011). This large contribution from the residential sector in the country could be explained by the fact that the Industrial and Transportation sectors are not yet well developed. There are different ways in which the residential sector energy consumption could be optimized. This research will focus mainly on the use of technologies and models that are efficient within the households as well as the adoption of efficient building, which could range from designing efficient building and use of efficient materials.

1.3. Objectives

1.3.1. General Objective:

The overall research objective is to assess the economic feasibility related to the implementation of energy efficiency measures in the residential building sector of Mozambique.

By implementing energy efficiency measures in buildings, the aim is to rationalize its energy consumption, avoiding wastes while providing users of the residential building with all the necessary services, as well as fulfilling the expected degree of comfort and functionality.

1.3.2. Specific Objectives:

- To assess energy consumption in the residential sector in Maputo;
- To detail the final end use of energy in the residential sector in Maputo;
- To compare the theoretical energy performance of conventional buildings and buildings employing innovative approaches of energy management;
- To perform a comparative analysis of the cost of buildings implementing energy efficient approaches with those associated with the conventional options.

1.4. Limitations

This research depended upon data provided by individuals, meaning that the quality of the collected data is directly co-related to the degree of importance that the surveyed households placed on the study. In case where the households showed interest to collaborate with the survey, the data was of relatively high quality, and the opposite is also true.

It is important to note that some peculiar difficulties were encountered during the process of data collection, particularly in *Sommershiled*. It was difficult to find the house's tenants willingly to participate in the study. The result of this situation was the reduced number of surveyed households, which dropped from 23 to only 3 houses, reducing the sample size from 253 to 233 households.

Although the study focused on all house types identified by the National Institute of Statistics (INE "*Instituto Nacional de Estatística*), only two types of houses represented the majority of the surveyed houses, namely apartment blocks and conventional houses (houses with single floor). Since one of the objectives of this study was to develop an energy efficient house, a base case that would be used to project the efficient design was necessary. The suggestion an efficient design for apartment blocks showed to bear many variables that would be difficult to keep track. Therefore, to overcome this limitation this investigation combined the data of apartment blocks and conventional houses. This combination made a distinction between each type of house, meaning that an apartment block of two bedrooms was combined with a conventional house of two bedrooms which resulted in what is designated as type 2 house and the same was done for the three bedrooms houses, resulting in type 3 house.

The proposed efficient design was considered to use ready available materials. The study only considered energy efficient strategies suggested by company A, which is basically the use of elements such as: roof and wall insulations; cross ventilation; double clear glazing; well oriented house as well as the use of window overhangs.

1.5. Importance of the Research

Since the advent of Industrial Revolution in the 17th century, the level of consumption of energy throughout the world has gained unprecedented momentum. This increase is, in part, responsible for the rise in the concentration of greenhouse gases (GHGs) in the atmosphere, consequently contributing towards climate change and its adverse implications on society (IPCC 2007; Mackay 2009).

UNDP (2000) argues that, no country has reached economic development without having to increase its energy consumption, at least during the early stages. Although developed countries are capable of growing economically without exerting significant pressure on their energy consumption, in developing countries the situation is different. In the case of the latter, each incremental dollar in gross domestic product (GDP) generally implies an increase in energy demand.

The increase in energy demand may have negative impact in future generations, as the energy resources that the world depends on are mostly finite and non-renewables. Therefore, securing the global energy future is of the utmost importance. International agencies including but not limited to IEA, IPCC, UNFCCC and UNDP indicate that a paradigm shift that could result in an immediate transition to a low-carbon economy is required. Reducing energy consumption for the same service is one of the ways in which this shift can be accomplished. In light of this, one of the 25 recommendations of the IEA indicates that governments should implement strategies to improve energy efficiency in buildings that are proven to be cost-effective and deliver the required positive changes in terms of energy conservation (IEA, 2010).

Over the last twenty years, building energy code schemes have been implemented by myriad countries, including all the IEA member states (IEA, 2013a). This instrument represents a key policy that assists governments in reducing the overall energy consumption in buildings (Kavgic *et al.*, 2010; Kelly *et al*., 2012). In parallel to building energy code scheme, energy performance certification has also been implemented worldwide with the same objective; it can be either mandatory or voluntary. For instance, the European Union Energy Performance of Buildings Directive (European EPBD) is mandatory for all the European Union countries. On the other hand, in the United States of America (USA) and Singapore, energy performance certification has been implemented on a voluntary basis. Similarly, appliances efficiency standard and labeling is also being implemented worldwide, to name but few, in the EU there is a scheme called Eco-Design under which appliances are rated and labeled, the same principle is also being massively implemented in USA under the ENERGY STAR scheme. These are clear examples of the available courses of actions that are being pursued by many countries in order to reduce their building sectors' energy consumption.

Mozambique, on the other hand, does not have any of these schemes in place, either in mandatory or even voluntary basis (EDM, 2012a). Nevertheless, as the country is a signatory to the Kyoto Protocol, actions to reduce its GHG emissions are necessary, and he mentioned schemes offer a possibility of reaching this global goal.

Kavgic *et al.* (2010) and Kelly *et al.* (2012) state that, in the absence of policy actions that will improve energy efficiency in buildings, this sector will continue to exert great pressure on primary energy supply and increase grid capacities. In Mozambique the scenario is even alarming as the *Hidroeléctrica de Cahora Bassa* (HCB – Cahora Bassa Hydroelectricity), the company responsible for electricity generation is currently operating in its full capacity, and the *Electricidade de Moçambique* (EDM – National Utility) has deficient grid capacity to meet the local demand. It is, therefore, in this perspective, that the building sector plays an important role, not only in improving the energy security and meeting the global goal of reducing GHG emissions by 50% by the year 2050, but also in reducing the need for additional power generation and grid capacity at a local level.

The level of energy consumption in conventional buildings is usually higher than that in modern and green buildings. Modern and green buildings make the transition from inefficient to energy efficient buildings possible. In fact, these buildings also provide other dividends such as low operational and maintenance costs. Therefore, providing measures that are cost effective to ensure massive adoption of these alternative buildings is critical. For instance, a recent study conducted in Finland indicates that minor increases in investment for new construction or in renovation of buildings may result in savings in primary energy consumption in the region of 3.8 – 5.3% by 2020, respectively (Tuominen *et al.,* 2013). Moreover, according to the European Commission (2010), with high performance buildings, it is possible to reduce total energy use between the years 2005 and 2020 by 20%.

The inefficient use of energy has adverse technical, economic, environmental and social impacts. Furthermore, up until now little has been done by the Government of Mozambique, and construction industry to widespread energy efficient measures and practices in buildings in Mozambique. However, by adopting small changes including improving insulation, using lower energy consuming lighting, using more efficient appliances, there could be a reduction of more than 50% in the annual energy demand in Mozambique (Hankins, 2009).

In Mozambique, as the level of energy consumption has been accelerating over the recent years, and is expected to continue increasing in the years to come, there has been a growing concern from the Government related to energy availability and affordability to all of its citizens (EDM, 2012a). Measures to promote the rational use of energy are required in Mozambique in order to ensure massive distribution of this resources and its affordability. It is therefore, in this perspective that this research aims to evaluate the existing potential in Mozambique for rational use of energy and energy efficient practices that enhance the reduction of energy consumption in buildings, particularly in the residential sector.

The evaluation of available potential that may boost the rational use of energy in the residential sector could, on the one hand, help building developers, real estate investors, house owners, and other building sector stakeholders to make their decision about building design options and type of appliances to use, taking into consideration energy efficiency parameters that reduce the overall energy demand of a building throughout its lifespan. On the other hand, it may also be used as a tool that the Mozambican Government could assess to develop policies and regulations that target this particular sector. The combined impact will be on improving the way in which energy is being used by the residential sector, thereby impacting positively on the overall energy balance of the country.

1.6. Thesis Outline

This thesis consists of five chapters. The first chapter is the introduction, where the global and local context related to energy consumption status in the residential sector is briefly discussed. This is followed by the indication of the main objective and specific objectives that guides this thesis. Additionally, the importance and outline of the thesis are also presented within the chapter. Chapter 2 presents a review of relevant literature on the subject under discussion. In this chapter, aspects such as the world energy status, the picture of energy use in the residential building worldwide and locally are discussed. In addition, the rationale for energy efficiency in residential buildings worldwide and in Mozambique, including current practices in building energy use and optimization, worldwide and nationwide use are also discussed in this chapter. Chapter 3 focuses on the methodology adopted to collect and analyze data. In this chapter, a brief discussion of the design of the research is presented. It is also in this chapter where a detailed methodology for data collection is described, followed by a brief discussion of the selected tools used to analyze the data. Findings from this investigation are presented and discussed in Chapter 4. The main conclusions and recommendations drawn from the findings are discussed in Chapter 5.

Chapter 2: Literature Review

The objective of this study was to assess the economic feasibility of implementing energy efficient measures within the Mozambican residential sector. Chapter 1 indicates the overall and specific objectives of this thesis. This chapter on the other hand, makes an assessment of the use of energy in the residential building at global and local levels and discusses its main drivers and implications. The advantages of implementing energy efficient measures and the current practices in energy use and optimization in buildings are also highlighted. It then examines energy efficiency building regulations and lastly presents a brief discussion of the strategies for achieving energy efficiency in the built environment.

2.1. What is Energy Efficiency?

Energy efficiency is generally defined as the act of using less energy to provide the same service (Patterson, 1996 and Rodriguez-Ubinas *et al.*, 2014a). According to Patterson (1996), energy efficiency can be determined with the following ratio:

$$\text{Energy efficieny} = \frac{\text{Useful output}}{\text{Energy input}} \qquad (2.1)$$

For instance, the energy efficiency of an electric geyser is equal to the ratio of the total thermal energy absorbed by water to the total energy input to the heating element(s) of the geyser. The concept of energy efficiency is different from that of energy conservation. Energy conservation is reducing or forgoing a service to save energy, which can be accomplished with or without energy efficient measures, depending on the elements that dictates the reduction. For example, while turning down or using less air conditioner in summer is a process of energy conservation, replacing incandescent light with compact fluorescent ones is an energy efficient action.

From the building point of view, the degree of its energy efficiency is usually linked to the incorporation of factors such as, but not limited to, building envelope features that are energy efficient and use of energy efficient appliances, to reduce the building energy requirement to provide healthy and comfortable indoor environment throughout its lifetime. Rodriguez-Ubinas *et al.* (2014a) concurs with this, and states that energy efficient buildings are those that combine not only passive design solutions but also active designs to reduce energy consumption, and indicate that passive design elements are usually more affordable than active design solutions.

2.2. The use of energy in the residential buildings worldwide

The world's energy consumption levels have been increasing rapidly over the last decades. This, then raises concerns regarding decrease on supply capacities, depletion of the energy resources, social and economic impacts due to the increase of energy prices as well as adverse environmental implications including but not limited to climate change, global warming as well as the depletion of the ozone layer.

IPCC (2007) report indicates that the most outstanding environmental problem that the human king faces currently is global warming. This problem is worsened by the constant and alarming increase of GHG emissions (Carbon dioxide – CO_2, Methane – CH_4 and Nitrous Oxide – N_2O) into the atmosphere. However, since the findings from this report indicate that the main reason for the increase in global temperature is the burning of fossil fuels, reducing energy consumption that stems from fossil fuels seems to be one way of reducing GHG emissions.

Most of the energy that the world consumes comes from non-environmental friendly sources, such as coal, oil, natural gas and other sources such as industrial waste and non-renewable municipal waste. In the current scenario where there is heavy dependence on carbon intensive sources of energy, high energy consumption level implies high levels of CO_2-eq. emissions into the atmosphere, therefore, curbing this scenario is of the utmost importance.

Figure 2.1 extracted from the IEA (2013c) elucidates that from 1971 to 2011, the world total final consumption more than doubled throughout the period in reference. Fossil fuels are basically the most relevant sources of energy all across the world, and Oil is by far the larger contributor, followed by electricity, Natural Gas and Biofuels. The key factors that could explain this trend are, economic and population growth.

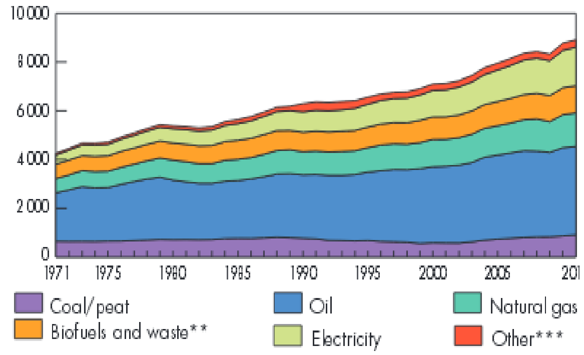

Figure 2.1: World* total final energy consumption from 1971 to 2011 by fuel (Mtoe).
*World includes international aviation and international marine bunkers
**Data prior to 1994 for biofuels and waste final consumption have been estimated.
***Other includes geothermal, solar, wind, heat, etc.
Data source: IEA (2013c).

Figure 2.2 illustrates the global picture of the world dependence on fossil fuel in the years between 1971 and 2011. Despite the slight reduction in the share during the period in reference, fossil fuels are by far the larger primary energy supply worldwide. From a total of 13113Mtoe of the world's Total Primary Energy Supply (TPES), fossil fuels represents 82% counter 18% of non-fossil sources.

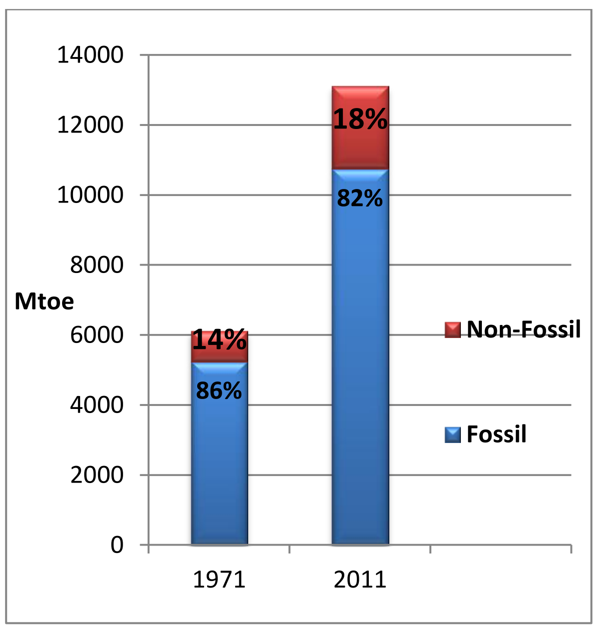

Figure 2.2: World primary energy supply, including international bunkers.
Source: IEA (2013b).

As previously indicated, the combustion of fossil fuels is responsible for increasing GHG emissions. Hence, CO_2 from energy related usage accounts for 60% of global emissions, and persist for longer than other GHG (Solomon *et al.*, 2008). Figure 2.3, indicates how CO_2 emission has evolved and the type of fuels that were the main drivers for the trend. From what is showed by the figure coal/peat are currently the larger source of CO_2 emissions followed by oil and natural gas.

The data presented in Figure number 2.1 and 2.3, indicate the positive correlation between the increase in total final energy consumption and CO_2 emissions between 1971 and 2011. According to Solomon e*t al.* (2008) the increase of CO_2 emissions into the atmosphere has severe environmental implications that are affecting the climate system negatively. IPCC (2007), states that this adverse implication is currently being verified with atmospheric warming, precipitation changes as well as sea level rise.

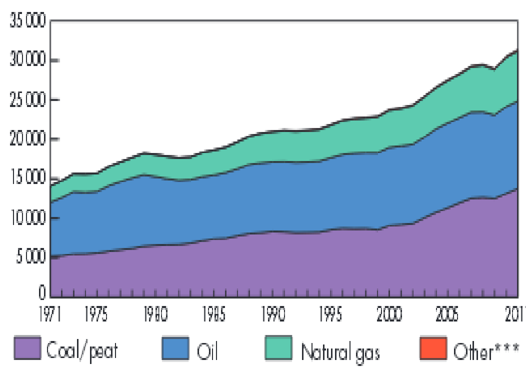

Figure 2.3: World* CO2 emissions** from 1971 to 2011 by fuel (Mt of CO2).
*World includes international aviation and international marine bunkers
**Calculated using IEA's energy balances and the Revised 1996 IPCC Guidelines.
CO_2 emissions are from fuel combustion only.
***Other includes industrial waste and non-renewable municipal waste.
Data source: IEA (2013c).

According to Figure 2.4, electricity and heat was the largest CO_2 producer in 2011, accounted for 42% of the world emissions, followed by transport and industry sector. Although the residential sector was directly responsible for only 6%, the perspective changes when taking into consideration that around 26% of the emissions from electricity and heat production was to supply the needs from the residential sector (IEA, 2013b). Figure 2.4 shows the percentages of CO_2 emissions according to each sector of economy.

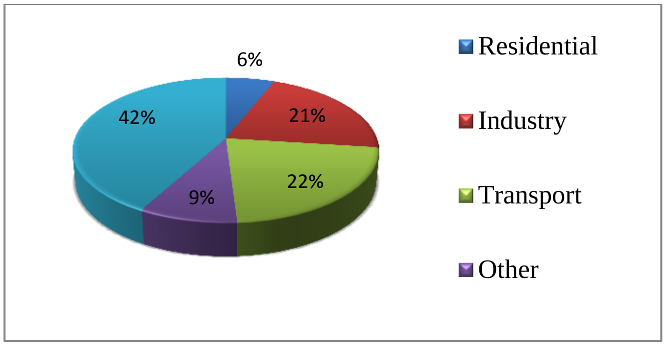

Figure 2.4: World CO2 emissions by sector in 2011.
*Other includes commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.
Data source: IEA (2013b).

There are myriad ways in which energy is used within the residential buildings. There are also differences in the consumption levels according to different climatic areas as well as the development stage of each region or country. Two distinctive extremes can be drawn, being one characterized as developing countries that are less industrialized and the service sector is still on its early stage of development. The share of the residential sector in the total energy consumption of these countries usually surpasses 75%. This group includes but is not limited to Mozambique, Zimbabwe, Angola, India, Ukraine, Greece and Turkey. The second extreme is constituted by countries that have their residential sector consuming in some cases less than 10% of the country's total final energy consumption, these countries usually have their industry and service sector well developed and the heating needs are considerably insignificant, for example Brazil, Namibia and Portugal (IEA, 2014a).

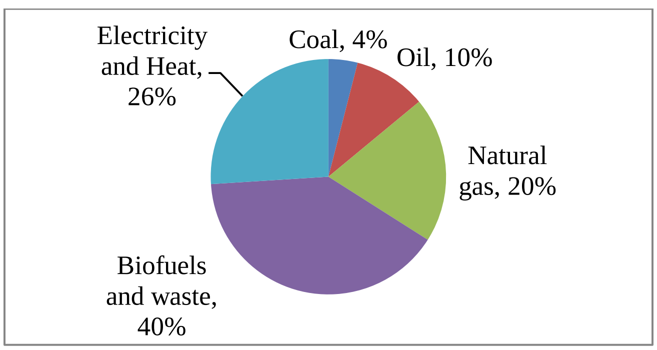

Figure 2.5: Share of various energy sources in the world residential energy consumption in 2011.
Data source: IEA (2014a).

Not only is the total final energy consumption different from country to country so do the share of the main energy sources in the residential sector worldwide. Figure 2.5 demonstrates that among all sources of energy of the residential sector, biofuels and waste represents the most important source, with a share of 40%, followed by electricity and heat, and natural gas, with shares of 26% and 20%, respectively. Oil and coal also contribute, however with minor shares of 10% and 4%, respectively.

The International Energy Agency (IEA) usually aggregates the main relevant final energy consumers in four groups, namely: industry, transport, residential and services. Figure 2.6 depicts the share that these sectors have on the total final energy consumption, and the total amount of energy consumed worldwide. The figures clearly indicate the significance of the residential sector in terms of final energy consumption, representing 23% of the total final energy consumed in 2011. However, it's worth noticing that the industry and transport sectors consumes even more energy than the residential sector, with shares of 29% and 27% respectively.

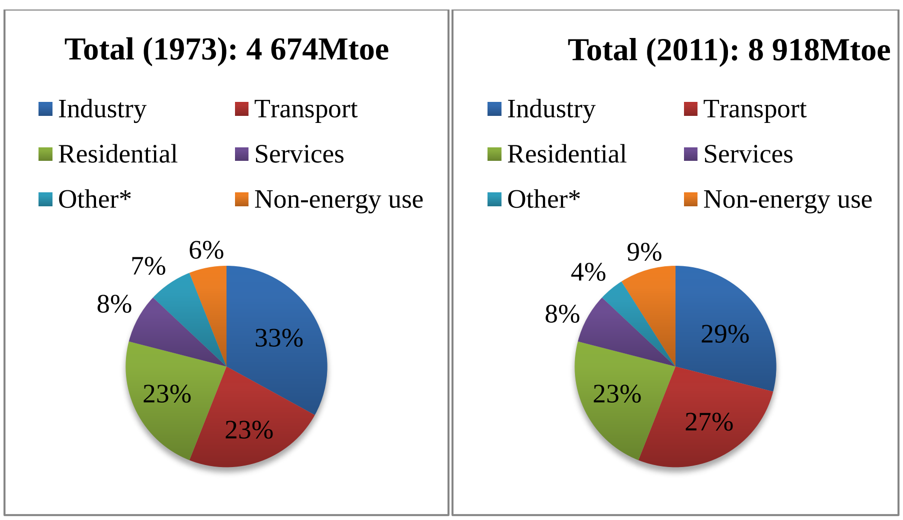

Figure 2.6: Shares of sectors in total final energy consumption for the world (1973 and 2011).
*Other includes agriculture/forest, fishing, non-specified.

Data source: IEA (2014a).

Although, the residential sector share on the total final energy consumption remained the same in 2011 as those from 1973, its level of consumption has increased, since in 1973 the total final consumption was only 4 674Mtoe counter 8 918Mtoe in 2011, which means that the sector total final energy consumption almost doubled. This, increase can be explained by the growth in population, increase in time spent in doors, rise of comfort levels as well as the pressure due to more building services.

Throughout its life cycle, the building demand for energy is both, direct and indirect. On one hand there is the direct energy demand occurring during the construction, operational and demolition phases. On the other hand, there is an indirect demand result from the extraction of the raw materials, the production of the materials needed for their construction and technical installations (Sartori and Hestnes, 2007). It is important to note that, different quantities of energy are consumed directly and indirectly, but the direct demand constitutes the bulk.

Studies carried out few decades ago by Hallquist (1987) and Hannon *et al.* (1987) cited by Gillingham *et al.*, (2006) indicated that 90-95% of the total energy required by a house during its lifespan was consumed during the operational phase. This figure clearly indicates the relevance of the building life cycle energy bill during the operational phase over other stages.

Later on, Adalberth (1997) performed a study in Sweden, whereby energy consumption in three single-unit dwellings during their life cycle was assessed. The study concluded that 85% of the total energy required by a building throughout its life cycle is used during the operational phase, followed by embodied energy (to manufacture all materials needed for the building's erection and renovation), accounting for approximately 15%. Moreover, the study concluded that transportation and energy process accounts for nearly 1% of the total energy during the building's erection and end of life disposal. These percentages, clearly indicate that if an intervention towards reducing energy consumption in the building sector is ever to be achieved, the emphasis should be in the building operational phase, since the energy consumed in other phases such as, construction, renovation, demolition are minor.

Subsequent studies carried out by Utama and Gheewala (2008) and Ramesh *et al*. (2010) conclude that embodied energy represented 10-20% and operating phase was responsible for around 80-90% of the house's total energy demand during its life time. Moreover, Beccali *et al.* (2013) also performed life cycle assessment in single family house in Italy, where it was concluded that operation phase represented 72% of the total energy consumed by the house throughout its lifespan and the remaining 28% represented the embodied energy. Another study with relatively different findings was performed by Islam *et al.* (2014) in typical Australian residential townhouses concluded that altogether, construction, maintenance and demolition represented 50% of the cumulative energy demand of the houses, and the operation phase represented the other 50%. The high percentage of the embodied energy can be explained by the fact that the study covered different buildings designs. The study target was comprised not only high star ratings houses but also those with lower star ratings.

It is important to note that, factors such as increased awareness of the damage that high demand of energy worldwide cause to the environment, are currently influencing positively towards the reduction of the building operational phase energy consumption worldwide. Findings from studies performed by Hasan (1999), Kneifel (2010), Ramesh *et al*. (2010), Mata *et al.* (2013), Beccali *et al.* (2013) and Islam *et al.* (2014) suggest that improvements in the building envelope design that comprises among other, higher insulation, daylight control, low energy intensive materials may contribute reducing energy requirements in the building operational phase at the expense of an increase in the embodied energy, mostly during the construction phase.

Despite the fact that, factors including however not limited to weather conditions, income levels, energy sources, consumers preference and behavior as well as building characteristics determinate the extent to which energy is consumed by the households during the period when the building is used for the reason it was erected, in general energy is used mainly for space heating, space cooling, lighting, cooking, water heating, and appliances (Swan and Ugursal 2009).

According to Pérez-Lombard *et al.* (2008), the larger energy consumer among the residential end-use is the Heating, Ventilation and Air Conditioning (HVAC). In the United States of America for example, HVAC was responsible for 50% of total final consumption in the residential sector, and accounted for 20% of the country's total consumption. The IEA (2008) desegregates the indicator, by evaluating only space heating and reports that between 1990 and 2005, space heating represented the larger energy end-user by households in selected IEA countries, ranging from nearly 14EJ in 1990 to almost 15EJ in 2005.

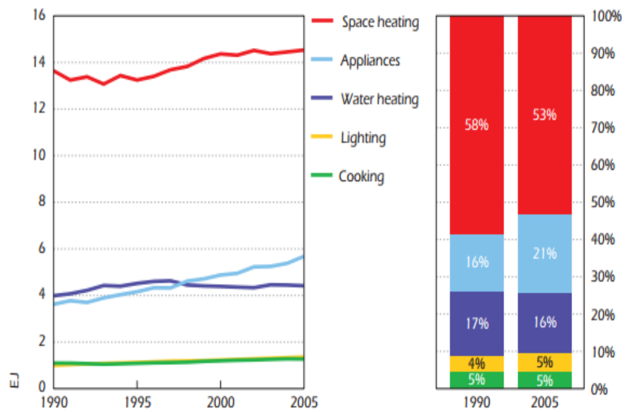

Figure 2.7: Household energy use by end-use in the IEA19.
Source: IEA (2008).

It is crucial to note that despite this upward trend, Figure 2.7 shows the decrease of space heating requirement from 58% in 1990 to 53% in 2005. The reduction could be attributed to the increased awareness of the households of issues related to global warming and its relation with increased energy demand as well as the improvements in buildings performance. Moreover, in terms of proportions, space heating accounted for 53% of the total household energy use by end use in 2005, followed by appliances (21%), water heating (16%), Lighting (5%) and cooking (5%). It is important to note that between 1995 and 2005 there has been a shift between appliances and water heating energy requirements. On the one hand, there has been a dramatic increase in the total energy use of appliances. On the other hand, water heating requirement showed a downward trend. The drop on energy consumption for water heating could be attributed to the growing number of households using modern renewable energy technologies such as solar water heaters.

The bulk of available scientific work in this area was conducted in developed countries, especially in Europe. Therefore, literature regarding the energy consumption patterns during the operating phase in developing countries is scarce. Nevertheless, a study conducted by Debnath *et al.* (1995), in India, which has relatively similar weather conditions and economic development as that of Mozambique, indicates that the energy required for the day-to-day activities of a house with $75m^2$ floor area accounts for 50% of the total life cycle energy requirements of a building that lasts for 30 years. It should be clarified that, despite the fact that India is currently categorized as a middle income economy and Mozambique still falls under the category of low income economy, the study in reference was conducted in a period where the economic characteristics of India were closely related to that of Mozambique in current days.

2.3. Mozambique and its energy profile

2.3.1. Economy and Development

Mozambique is a developing country located in Southern Africa with a warm and tropical climate. According to the National Institute of Statistics (INE - *Instituto Nacional de Estatísticas*) during summer the countries temperatures fluctuates between 24.1 ˚C and 41.5˚C, however, in wither it ranges from 7.4˚C and 26.5˚C. The last census conducted in 2007 by INE indicates that the country has around 20.07 million people. However, current estimation indicated this number to be over 25.83 million people (World Bank, 2014). INE (2007) indicates that over 70% of the Mozambican populations were living in rural areas. However, this number has been shrinking as time goes by, caused mainly by rural exodus. In fact, current figures indicate that in 2010 the percentage dropped to approximately 62% (World Bank, 2014).

Figure 2.8: Mozambique map.

Mozambique is the thirty fifth largest country in the world, with an area of 802,590 km^2 divided between land and water, with shares of 785,090km^2 and 17.500km^2 respectively. Figure 2.8, shows the Mozambique Map. The Map depicts that Mozambique shares border with six countries, namely, South Africa and Swaziland to the southwest, to the northwest there is Zimbabwe, Tanzania to the north and to the northwest it shares border with Malawi and Zambia.

Portuguese is the official language inherited from Portugal, which colonized the country. There are 10 provinces in Mozambique, namely, Maputo (Capital City), Gaza, Inhambane, Sofala, Manica, Tete, Zambézia, Nampula, Cabo Delgado and Niassa. The capital city, which is located on the western shore of Maputo bay, at the southern end of the country, occupies the central position in terms finance, policymaking, commerce, education and Infrastructure.

There are three main stages that mark the economy of Mozambique. First stage happens prior to the proclamation of the country's independence in 1975, when Portugal dominated the country, and the economic development followed the rules and expectation of the colonizer. The second stage happened during 1977-1992. During this period the country suffered from a civil war, led by the two main parties "*Frente de Libertação de Moçambique"* (FRELIMO) and *"Resistência Nacional de Moçambique"* (RENAMO). Not only did the war decimated lives, but also resulted in huge sabotage of the industry as well as the devastation of most of the infrastructure inherited after the independence. This situation drove the country to complete chaos, and stepped back the country development goal adopted after the independence. The last stage started after the peace agreement between the two parties, from this period started a new era of democracy and multiparty system. Since then, the country has experience unprecedented economic growth rates.

Currently, Mozambique is member of Southern Africa Development Community (SADC). According to the United Nation Development Program report, the country remains steeped in poverty, despite the optimistic speeches from the politicians. The country is at position number 178 out of 187 countries, which represents a rose by seven places in overall score in comparison to the 2012 position, moving from position number 185th in 2012 to 178th in 2013 (UNDP, 2014). Although the country is endowed with rich and extensive natural resources, its benefits are yet to be evenly distributed among its citizens. This situation could explain the contradicting information regarding the Mozambique economic growth and level of poverty alleviation.

The Foundation for Community Development, states that poverty levels have worsened, current estimation indicates that there has been an upward trend from 54% in 2009 to 60% in 2013. According to the International Monetary Fund (IMF), in 2013 Mozambique presented a Real

Gross Domestic Product (GDP) of 7.1% which was one of the highest within sub-Saharan Africa. Moreover, the projections from the IMF indicated that the GDP may reach 8.3% and 7.9% in 2014 and 2015 respectively. This growth is mainly driven by the increase of public expenditure as well as the foreign direct investment. However, the country's fiscal revenue only covers 65% of the annual budget.

The mining sector was the fastest growing sector in 2013, mostly due to the increase in coal exportation. Agriculture still plays an important role in the countries income, currently, it employs and provides livelihood to over 70% of the population, and according to Cuvilas *et al.* (2010), the sector employs 80% of the labour force. The sector is not yet well developed, and the majority of its players practice subsistence agriculture, which has a very small productive rate. The industry sector was reasonably developed prior to the independence from colonial rule, thus, the war against the colonialism followed by the civil war resulted in the destruction, sabotage and foreclosure of many industries.

Figure 2.9, elucidates the country's situation in comparison to the neighboring countries. Mozambique has the lowest GDP per capita, South Africa and Botswana are the ones with the higher GDP per capita.

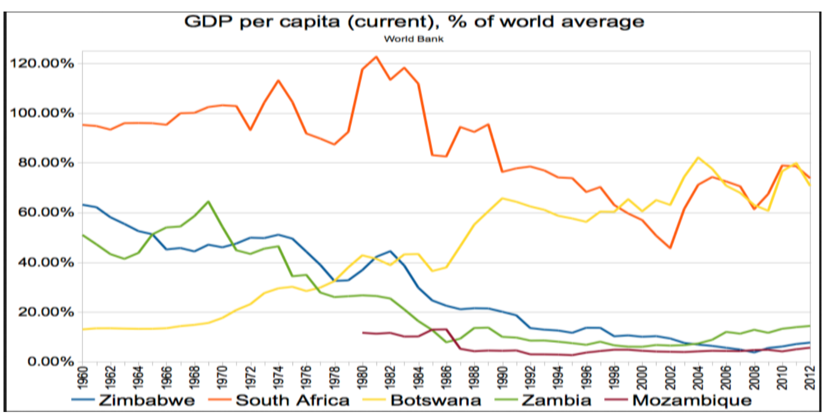

Figure 2.9: GDP per capita, compared to neighbouring countries (world average = 100).
Data source: World Bank (2013).

2.3.2. Energy profile

Biomass precisely primary solid bio-fuels, Hydropower, Oil and Oil products, Natural Gas as well as Coal and Coal Products constitute the country's energy portfolio (Cuvilas *et al.*, 2010). According to Figure 2.10, during the year 2011, biomass represented 78% of total primary energy supply, followed by hydropower (13.8%), Oil Products, (7.9%), Natural Gas (1.2%) and Coal and Peat with a share of only (0.2%).

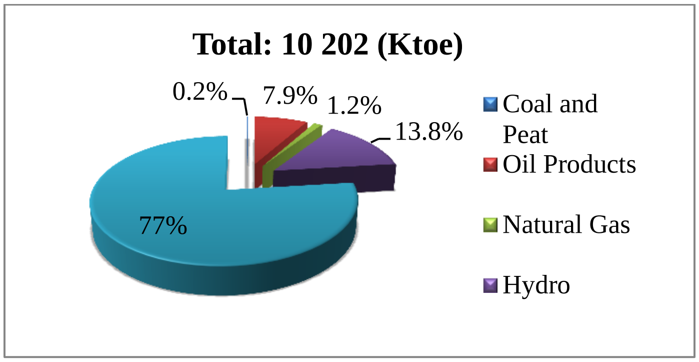

Figure 2.10: Total Primary Energy Supply in 2011for Mozambique.
Data source: Adapted from IEA (2013d).

In Mozambique, traditional biomass is being largely used not only by the rural households, but also by many poor urban and *peri*-urban households. A study carried out by Brouwer and Falcão (2004) estimates that in Maputo, 70-80% of the households use firewood and charcoal to meet their energy requirements. It is therefore, important to mention that the collection of wood fuels is mostly made in unsustainable manner. Additionally, Cuvilas *et al.* (2010) argues that, the use these fuels is usually made in inefficient ways, which contribute to significant energy losses, and deterioration of the household health conditions, causing severe respiratory diseases.

The lack of awareness of the potential damage caused by the unsustainable way in which biomass is collected is held responsible for the alarming cases of deforestation, forest degradation, soil erosion as well as land use change. Annually, over 22 million tonnes of firewood and charcoal is being produced in Mozambique (Cuvilas *et al.*, 2010). This situation then exacerbates the adverse impact in the environment, the climate system, the economy as well as to the society.

Despite the fact that Mozambique is endowed with significant amounts of coal, estimated at 20 billion tones in the Zambezi coal basin, up until now, the country still falls under the category of less carbon intensive economy, accounting for 0.01% of global CO_2 emissions in 2010, driven mostly by the cement industry (Solomon *et al.*, 2014). This relative low CO_2 emission is mostly because, on the one hand, the bulk of coal production is exported. On the other hand, there is use of hydro resources to generate electricity in the country. However, this situation may change in the coming decades.

According to Carneiro and Alberto (2014) and Solomon *et al*. (2014), the recent discoveries made at Rovuma basin indicate this basin to have a plethora of natural gas reserves, accounting for 100Tcf of gas, which could turn the country into one of the large natural gas producers in the world. In this line, the government goal of building a Liquefied Natural Gas plant near to the Rovuma basin, combined with the consideration of building a Coal-to-Liquids plant with 9GW installed capacity, it is likely that CO_2 emissions of the country will increase as these projects come to realization (Carneiro and Alberto, 2014; Solomon *et al*., 2014).

Mozambique's total energy consumption is about 8078ktoe, which is relatively low when compared to countries such as South Africa and Brazil, which consumes 71127 ktoe, 217889 ktoe respectively. On the other hand, Zimbabwe's total energy consumption is of about 8444ktoe, which is quite similar to that of Mozambique (IEA 2013d). South Africa and Brazil have a very energy-intensive industrial sector, which consumes a great deal of the total final energy within their economies. On the other hand, in countries such as Mozambique and Zimbabwe the residential sector is the larger final energy consumer, accounting for more than 50% of the total consumption. According to Figure 2.11, in Mozambique, the sector is responsible for 70.8% of the total final consumption, followed by the Industry, Transport, Non-specified, Commercial and public services and the agriculture and forestry sector, with shares of, 19.9%, 7.9%, 0.7%, 0.6% and 0.1%, respectively.

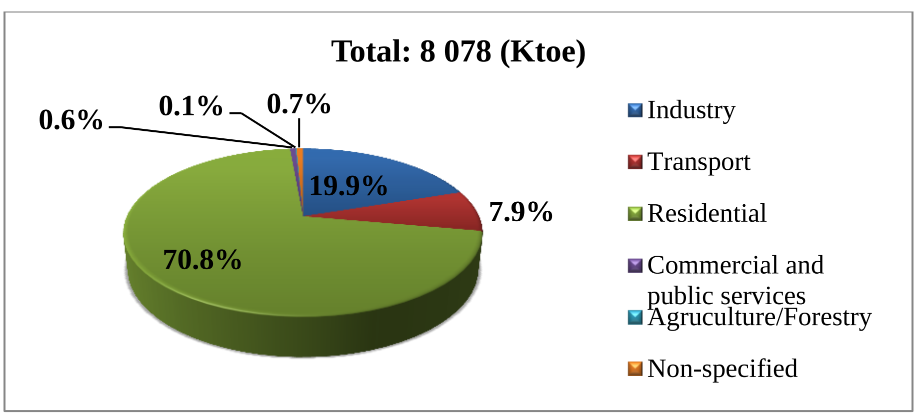

Figure 2.11: Total final consumption in 2011for Mozambique.
Source: Adapted from IEA (2013d).

2.3.3. Energy consumption in the Mozambican Residential Sector

Most of the households in Mozambique rely on traditional biomass to meet their energy needs. According to Figure 2.12, between the years 2007 and 2011 there was an increase of nearly 10% of the total energy consumption of the residential sector. Despite this fact, the share of bio-fuels and waste remained constant during the period, with an average of 98%. Electricity is the second main source of energy in the residential sector, accounting for nearly 2% of total energy consumed during the year 2011. This data concurs with the findings from IRENA (2012) and Cuvilas *et al.* (2010), which reports that only 18% of the population is connected to the national grid. This percentage places the country in the group of those with lowest electrification rates.

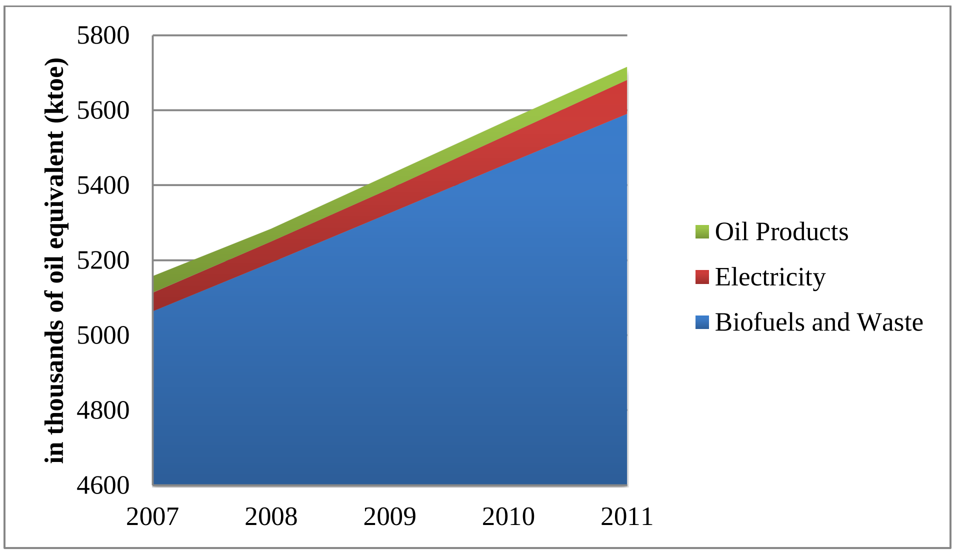

Figure 2.12: Energy sources of the residential sector between 2007 and 2011.
Source: adapted from IEA (2013d).

Figure 2.13 indicates that the residential sector was responsible for consuming 91% of the total electricity dispatched by the EDM between 2005 and 2010, during this period 8.35% of the total electricity was demanded by the commercial sector, and not surprisingly the Industry and Agriculture consumed less than 1% of the electricity. Moreover, according to Cuvilas *et al.* (2010) regardless its nearly insignificant share in the total energy consumption, gas consumption showed an unprecedented growth of its participation in electricity generation and in the residential sector during 2000-2006.

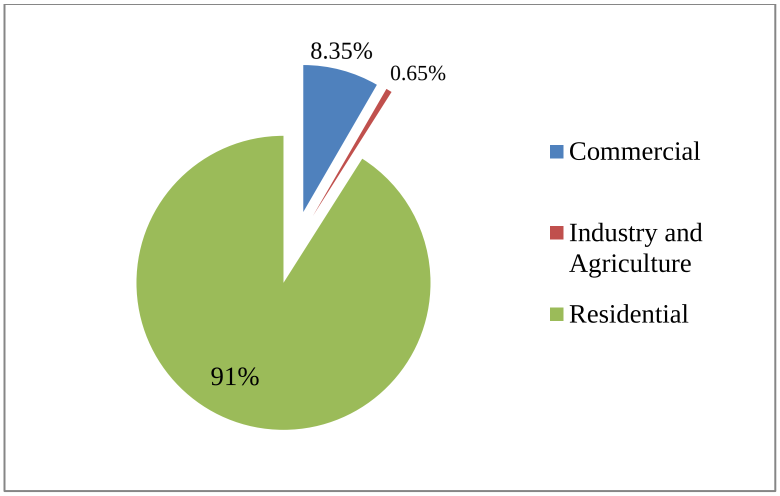

Figure 2.13: Sector share of electricity consumption from 2005 – 2010 for Mozambique. Data source: EDM (2011).

There is no disaggregated information in respect of the country's energy end use by the households in Mozambique. In 2013, the state-owned entity EDM, responsible for managing the national transmission grid for electrical power conducted a survey in Maputo Province that focused on the main end uses of electricity. This study was conducted in three districts, namely, Maputo, Matola and Boane. The survey covered a universe of 1217 households based on a random sampling technique. It covered a myriad of electrical appliances that are commonly used within the households. The main findings are presented in Table 2.1, which indicate the household's main energy use by end-use.

Table 2.2 aggregates the data based on the widely known energy end uses, such as, space heating, appliances, water heating, air conditioning, lighting and cooking. This aggregation makes it possible visualize the image of Mozambique in relation to the International scenario, in terms of households main energy end-use.

From what is indicated in Table 2.2, appliances represent 62.8% of the total kWh consumed in the surveyed houses, which represents the larger energy end use. Not surprisingly, there is no space heating requirement, which could be explained by the fact of Mozambique having a warm and tropical climate. This then would have raised a question about cooling requirements, which in this case represent a small percentage of 1.8%. The answer to this question is that the majority of the Mozambicans are unable to purchase cooling machines such as air conditioners and fans, worsened by the fact that the usage of these devices increases the household electricity bill.

Table 2.1: Household energy use by end-use in selected houses from Maputo, Matola and Boane in 2013. Data source: EDM (2013).

Item	Description	total kWh/year (%)
1	Freezers	32.00
2	Lighting	18.3
3	Televisions	10.4
4	Electric Geysers	8.4
5	Stoves	7.6
6	Kettles	4.7
7	Ironing Machine	4.4
8	DVD	2.1
9	Air Conditioner	1.8
10	Fans	1.7
11	Microwaves	1.6
12	Refrigerators	1.4
13	Sound Amplifiers	1.4
14	Radios	1.1
15	Ovens	0.7
16	Decoders	0.6
17	Computers	0.5
18	Dryers	0.4
19	Stabilizer	0.1
20	Monitor	0.1
21	Water Pumping Machine	0.1
22	Engine	0.1
23	Vacuum Machine	0.1
	Total	99.60[1]

Table 2.2: Aggregated household energy use by end-use. Data source: EDM (2013).

Item	Description	Total kWh/year (%)
1	Space Heating	0.0
2	Appliances	62.8
3	Water Heating	8.4
4	Lighting	18.3
5	Cooking	8.3
6	Air Conditioning	1.8
	Total	99.6

[1] The remaining 0.4% constitutes energy consumption of appliances that have marginal contribution, such as washing machine, blender, chargers, vaporizer, printers, portable computers, etc.

The table in reference indicates that there is a small amount of energy usage from the surveyed households that is currently being used for cooling, and to a lesser extent this is applicable to electric geysers for water heating. This is not because there is no need. Ideally, all households should have cooling and heating devices installed in their houses. On the other hand, freezers alone consume over 32% of the kWh per year; this value differs from findings of other countries, such as South Africa, where electric geysers are the larger energy consumer. From the study carried out by EDM, they consider freezers to run for 22hours per day, ignoring the runtime ratio of the appliance (EDM, 2013).

The information presented in Table 2.2, bolds the great difference from what happens in many, if not all, poor countries and developed countries. For example, space heating requirements in developed countries is nearly 53% (See Figure 2.7), however, in Mozambique the requirements is almost 0%. Moreover, when looking at appliances the differences is also dramatic, in Mozambique, the household's larger energy end-use is appliances, representing nearly 63% of the total energy bill. On the other hand, in developed countries appliances represent only 21% of the total energy consumed by the households.

It is important to note that, most households do not only depend on electricity to meet their energy needs, a significant number of households in urban and *peri*-urban areas rely on other energy sources such as Liquefied Petroleum Gas (LPG), charcoal, firewood and kerosene. These alternative sources are used for cooking, water heating and other end uses. Moreover, some families use electrical kettles for water heating, which in some cases is a substitute for electrical geysers.

2.3.4. Economic performance of buildings in Mozambique

In Mozambique, little has been done to improve buildings energy performance. It also should be noted that literature on this subject is scarce in Mozambique. However, there are some reported works. For example, a study carried out by Wu (2012) that analyses data from 1997-2006 in 19 countries in Africa, including Mozambique, concluded that Mozambique is one of two countries with unsatisfactory energy efficient rate during the period in reference, when elements such as, energy consumption, electricity transmission and distribution losses were taken into consideration.

The study carried out by Gabriel Auziane in 2010, is one of the first in the field of buildings energy efficiency in Mozambique. The aim of the study was to evaluate buildings energy performance in Maputo through modeling and simulations of energy use in buildings. To do that, the study used technical instruments and methods such as Energy Barometer, which was used to monitor climate data and DEROB-LTH Program (Dynamic Energy Response of Buildings – Lunds Tekniska Högskola) used to estimate energy use, indoor thermal climate and visual comfort in buildings. Furthermore, the building under which the study was performed is located in the City of Maputo. It belongs to the Faculty of Engineering of the Eduardo Mondlane University, and is called "3 *de Fevereiro* Building".

The measurement instruments were installed in the houses from June to September 2009, to monitor and evaluate the indoor and outdoor temperature and humidity, wind speed and direction, global and diffuse solar radiation and rainfall. By assessing these elements, it was possible to determine the building energy performance and its additional energy requirements for HVAC to provide the households better indoor comfort. On the one hand, the study found that, the building main façade is south oriented, which is in accordance with the principles of good orientation, this principle is explained in detail further in this thesis, under the topic, strategies for achieving energy efficiency in the built environment. On the other hand, despite this attempt, the energy performance of the building in reference is very low, because energy in being used in an inefficient manner.

2.4. Advantages of Energy Efficient Measures Implementation

The International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) have gathered important data regarding energy consumption trends and climate change, respectively. The IEA (2013b) states that, the total final energy consumption has increased from 4 674Mtoe in 1973 to 8 918Mtoe in 2011 representing 52.4% of increase. Along with this, there has also been an upward trend of GHG emissions into the atmosphere, according to IEA (2013b) emissions in 2011 were twice from those verified in 1973. Furthermore, as indicated by the IPCC (2007) observational evidence shows that there has been a dramatic increase of the global surface temperature over the last two decades. This increase is being driven by the increase of the anthropogenic GHG concentration in the atmosphere. Predictions from both IEA and IPCC indicate that this trend will continue in future, and will be driven mostly by emerging economies such as Brazil, China, India, South Africa and Middle East countries.

The building sector alone, accounts for 40% of the total end use of energy in most countries across the world (IEA, 2013). Although the potential for energy efficiency improvements in buildings has been neglected in many countries, there is great potential for improvements that would contribute to the reduction of the building sector energy requirements provided that energy efficient approaches are considered (Beccali *et al.*, 2013; Lutz *et al.*, 2006; Pérez-Lombard *et al*, 2008; Ramesh *et al.*, 2010; Tuominen *et al.*, 2013). The decrease in final energy consumption would potentially improve the climate system as well as the society wellbeing at local and international levels. Moreover, the downward trend of final energy consumption in this sector may also help reducing energy dependence in countries where part or all of the energy consumed is imported.

Acknowledging this, the building sector has been indicated to be the heart of the 21st century's challenge by the IEA, and it argues that, by 2050 this sector may well contribute to the reduction of around 1 509 Mtoe that the world consumes, consequently a significant amount of GHG emissions could be reduced, since most countries rely on extremely polluting energy sources (IEA, 2013a).

At a global level, the residential sector is responsible for over 23% of the total final energy consumption (IEA 2013d). On the other hand, in Mozambique this sector is held responsible for consuming over 70% of the total energy consumed within the country during the year 2011, which clearly indicate the relevance of implementing energy efficient measures within the sector. Lovins (2004) states that, the most important benefits that can result from implementing energy efficient measures range from: avoiding direct economic and environmental costs as well as improving energy security.

2.4.1. Improving Energy Security

According to EDM, currently Mozambique demands for around 750MW to meet its electricity needs. However, the country can only obtain 500MW from Cahora Bassa Dam (HCB - *Hidroeléctica de Cahora Bassa*), 150MW is purchased from South Africa and the remaining 50MW are supplied by three small scale hydropower plants, namely: Chicamba, Mavuzi, and

Temane (EDM, 2012a). It is important to note that HCB is the company that is responsible for power generation in Mozambique and has an agreement to supply over 750MW to South Africa, and currently the power plants are operating at full generation capacity (de Brito *et al*., 2008). This situation is critical for Mozambique when looking at the energy security of the country. The electricity that is purchased from South Africa is expensive for the Mozambique scenario where electricity prices do not meet the costs incurred for generating, transmitting and distributing it to the final users. Moreover, according to EDM (2012a) the country has now reached its demand peak, which means in the absence of additional power production capacity the country may well suffer from power shortage.

2.4.2. Curbing the Economic costs

Energy is a scarce commodity, and has significant costs to its users. These costs are usually prohibitive in most low income economies, and they can either be financial or opportunity costs. In case of poor countries, where a significant number of families are living under the poverty line, energy affordability is of great concern to these families (Culillas *et al.,* 2010). Therefore, the reduction in energy demand, may contribute towards increasing energy availability, consequently it could improve its affordability to low income households (UNDP, 2000).

From the macroeconomic point of view, the dependence on imported energy could be reduced provided that the country gives privilege to the buildings that consumes less amount of energy than what a conventional one would otherwise require and reduce the countries burden for energy purchasing. The financial resources saved could be used to finance other pressing developmental projects of the country (IEA, 2008). In Mozambique, for instance where the Government has tremendous difficulties to finance primary need for the communities, such as adequate education, housing and health care system the potential financial savings could be used to address these issues.

Not only is the energy security a concern with respect to the need of implementing energy efficiency measures but also is the need to contribute towards more sustainable economy. This sustainability could be reached by promoting policies that can contribute toward improving the climate systems as well as the environment (Lovins, 2004). Therefore, measures that could influence people's behavior towards energy consumption patterns and awareness of the importance of energy efficiency could have positive impact in the national energy security, to the environment as well as enhancing sustainable development.

2.4.3. Avoiding Social and Environment implications

Modernizing ways in which buildings are constructed, would moderate the energy end use in these buildings, which have direct implication in the reduction of the GHG emission that pollutes the environment. In developing countries, such as Mozambique, where the majority of the population relies on traditional biomass to meet most of their energy needs, air pollution is critical.

Biomass burning is responsible for causing severe respiratory ailments as well as environmental problems, including but not limited to land degradation and deforestation (UNDP 2000). This situation is worsened by the fact that the majority of the houses of the poor households are usually poorly ventilated. On the other hand, efficient buildings are usually ventilated adequately, which provides the residents with better indoor climate conditions and reduces their cooling or heating needs. In comparison to conventional buildings, efficient building in this case will lessen the energy bill to the owners, and reduces fuel poverty.

2.5. Current practices in building energy use and optimization

The extent to which citizens of different countries are aware about energy related issues depends greatly on the development stage of the country they live in. People leaving in developed countries are usually well informed about energy security, climate change, the exhaustion of fossil fuels, global warming, and other energy related issues. So it is no secret that most of the practice that involves reducing the quantity of energy that is required to deliver the same output that would have been otherwise delivered with high energy quantity is not broadly adopted by poor countries. Moreover, energy efficient measures are generally misunderstood and considered to be costly.

Both, new and existing buildings present great potential for energy savings. The more energy efficient practices and measures are implemented the greater are the possibilities for energy cost reductions. Islam *et al.* (2014) and Mata *et al.* (2013) concluded that, the investments that are made to reduce energy consumption of a particular building are usually recovered in short to medium term, because of the consequent reduction in energy requirements for the building. In developing countries where new buildings constitute the bulk of the existing buildings, the potential savings at a national scale are even larger, because of their long lifespan (over 50 years), and the savings will occur throughout the building life time. These savings could be equally profitable at a macro-economic scale, should a national policy be considered.

Energy efficiency policies have been broadly implemented by the bulk of developed countries. These policies have been driven not only by the increase of energy price, but also to meet the Kyoto protocol targets, which were binding to all of its signatories. Moreover, other countries that were not signatories of the 1997 Kyoto Protocol, such as United States of America and China, which consume a great deal of energy and are also responsible for emitting a larger proportion of GHG, have adopted energy efficiency policies. Generally, their policies range from:

2.5.1. Building energy codes

Building codes are a set of rules and standards that should be considered while erecting a building. It has mostly to do with safety, public health, fire safety and ways of addressing energy efficiency in buildings. This instrument has been widely adopted by many countries for many years. However, since the begging of its implementations up until now, the building codes evolved and turned more complex, yet with significant impact in the building energy consumption. In order to rate buildings according to their energy performance, different rating schemes have been implemented across the world. Rating building energy performance enables tenants and buyers to compare performances between energy efficient buildings and those that are not. The resulting data could influence buyers' purchasing decision or owners to make their investment decisions, either for repairmen or alterations of the building envelope.

Liu *et al.* (2014) conducted a study in China, which focused on a project developed in Wanke city. Their study aim was to analyze energy performance of green buildings employing energy efficient technologies. The main finding of the study was that energy efficient technology applications results in high energy performance buildings, which brings not only economic benefits, but also environmental benefits.

IPCC (2007) consider the building codes as one of the policy framework that police makers should consider as an adaptation measure to minimize building energy consumption and curbing climate change. Moreover, it also argues that the success of this and other measures depends greatly on the government leadership, either in enforcing laws or by purchasing energy efficient products.

A very significant number of governments throughout the world are implementing buildings code schemes. In EU for example, building certification can be either mandatory, or voluntary. Although other member states started decades ago implementing building code, a mandatory scheme was first established in 2002 under the 2002/91/EC on Energy Performance of Building Directive (EPBD), which binds its entire members to implement energy performance certification and its main goal was to reduce building energy consumption. This directive was followed by its revision in 2010, resulting in the Directive 2010/31/EU (Marszal *et al*., 2011).

Other mandatory building codes are also being implemented currently in Australia and Japan, namely, ACTHERS and TGLSC respectively (Sayce *et al*., 2009). On the other hand, voluntary schemes including but not limited to, ENERGY STAR, Leadership in Energy and Environmental Designs (LEED), Green Point are currently being implemented in USA. However, LEED, argues, Sayce *et al*. (2009), different from Energy Star, which focus mainly on the building energy performance, is the main voluntary rating tool and targets various aspects related to the building. Moreover, other voluntary tools such as Green Mark, Minergie, Building Research Establishment Environmental Assessment Method (BREEAM) and Green Star, are also being implemented in Singapore, Switzerland, United Kingdom and Australia, respectively.

2.5.2. Setting standards and labeling for appliances

Adopting more efficient lighting, by replacing incandescent lights by fluorescent light, has reached a common agreement that reduces significant amount of energy that would have been otherwise consumed by the former. Use of more efficient devices including but not limited to, heating and cooling devices, efficient electrical appliances as well as improved cook stoves.

Appliances labeling is not a new concept, in fact, it is a widely known and implemented technique in most developed countries, including but not limited to EU and USA. The Directive 79/530/EEC from the EU established in 1979 marks the first steps towards labeling household appliances. Later on, the Directive 2010/31/EU is even more emphatic, in involving all intervenient, from manufactures, retailers and buyers responsibilities. Furthermore, according to Fuerst and McAllister (2011), in EU the use of eco-labels is mandatory in all EU members. In USA, argues Gillingham *et al.* (2006) the use of appliances labeling was enforced in 1987 by the National Appliance Energy Conservation Act (NAECA).

2.5.3. Providing financial incentives programs

Despite the fact that, the adoption of energy efficient measures resulting in the reduction of energy bill, the upfront costs to adopt these measures are usually high and more likely to disperse potential investors. These investments can be either for small appliances that are energy efficient or even to buy or construct a building. Financial incentives can be in the form of government subsides, taxes reliefs on certain goods that are energy efficient, loan programs or more directly, by promoting programs that allows energy customers to have financial benefits from the adoption of certain energy efficient technologies of behavior (Gillingham *et al.,* 2006). For example, if a particular country intends to replace incandescent light bulbs with fluorescent ones, if the upfront cost is high for the customers, the Government could subsidize the costs and will guarantee adoption of the technology. It is in this context that financial incentives programs are critical for energy efficiency measures, if the desired outcomes are ever to prevail.

Another good example for the provision of financial incentives that is being successfully implemented worldwide is the Demand-Side Management. The Demand-Side Management (DSM) is a system whereby, the electrical utility uses different schemes to limit peak electricity loads, by dispersing customer’s electricity use. This can be done by charging higher prices during peak times and lower rates when there is less demand (Rankin and Rousseau, 2008). An example of effective demand side management programs can be found in South Africa, a country underwent an acute power shortage in 2008, as a result, in 2010, the country promulgated a policy to support the energy efficiency and demand side management (DOE, 2010). This policy enforced what was already being done by Eskom; the National State owned utility, since 2004. However, the scope and targets of the Eskom program has since evolved and widen. Not only do the program target households but it also have to do with the industrial sector.

2.5.4. Providing information and voluntary programs

Well informed people are more likely to make better energy related decisions. These decisions could be for instance, adopting alternative energy sources that are cost effective, use of appliances that are energy efficient or choosing energy efficient buildings over non energy efficient ones.

In the absence of effective channels to disseminate information regarding available voluntary programs relating to energy efficient practices, the program degree of success will be very limited. In this perspective, providing accurate information about to all those mentioned actions for energy efficiency practices, play a vital role in the attempt to turn the world more energy efficient.

The provision of accurate information makes it possible to reduce problems related to market failures, which is driven by environmental externalities and imperfect information. In fact, it diminishes room for speculation, and makes it possible for all stakeholders to make their decision based on reliable information. Moreover, as argued by Howarth *et al.* (2000) this strategy is responsible for the success of the program developed to foster the deployment of energy efficient technologies through voluntary programs in the United State of America.

2.5.5. Zero Energy Buildings

Zero energy building is still a relative new concept. Its assumption is that the building relies mostly on renewable energy that is generated and distributed by a certain electricity utility to meet the bulk of its energy requirements (Marszal *et al.*, 2011). Despite its infancy stage, there have been remarkable developments in placing policies for its future implementation worldwide.

The Directive 2010/31/EU on the EPBD foresees a "nearly zero energy building" by 2020 for all new buildings. Additionally, in the USA a target of net zero for all new commercial buildings, was established under the Energy Independence and Security Act of 2007 (EISA 2007) to be attained by 2030. With zero energy building three potential dividends are likely to be accomplished, namely, reduction of building energy demand, reduction of the relative CO_2eq. emissions, and increase of the renewable energy share globally.

2.6. Energy Efficiency Building Regulations

The Strategy of the energy sector in Mozambique was promulgated in 2009, and indicates the efficient use of energy in its main principles (*Ministério de Energia*, 2010). However, up until now there are no clear policies and regulations that are being implemented regarding energy efficiency in Mozambique.

Although the CNELEC (*Conselho Nacional de Energia* – National Energy Council) the national energy regulator, is among other responsibilities, allegedly in charge to develop or analyze regulation proposals for the electricity supply industry that may be necessary and useful, as well as promote the execution of relevant legislation for the electricity supply industry, there are contributions of this council in terms of energy efficiency policies and practices promotion. In addition to this, the Ministry of Energy has no clear policy that could enhance energy efficiency practices in the country.

Regardless of these facts, EDM has endeavored to set an strategy that could guide the country to be energy efficient aware by submitting proposals for energy efficient strategy, and a proposal for banning incandescent light bulbs, which are yet to be approved by the Government (EDM, 2012a).

Within the Ministry of Energy there is the National Directorate of Electricity. This Directorate has the function of promoting the efficient use of electricity. And yet, so far there is no clear policy or regulation that indicates any intention of the government to implement the adoption of energy efficient measures(*Ministério de Energia*, 2010).. This lack of government leadership is resulting in the current situation verified in most households, where they are not aware of the relevance of energy efficient measures (EDM, 2012a).

2.7. Strategies for Achieving Energy Efficiency in the Built Environment

Buildings participate actively in the consumption of energy through thermal exchange between indoor and outdoor environment. In hot climates the thermal gains are larger and, together with the internal gains of occupancy and equipment and lighting, it produces a thermal load that is usually compensated by air conditioning systems. Therefore, the building envelope features can increase or minimize heat absortion.

Designing a houses with relatively minimum energy requirement throughout its lifespan and still provide a healthier, comfortable and aesthetic enviromnent for the homeownes is one of the biggest challenges for house projectors and designers lattely. Despite the fact that, up until now, energy efficient houses solutions are said to require relatively high initial investments when compared to a typical house, many studies have proven that when looking at the long term, efficient designs are the most cost effective solution, not only for the investors point of view, but also at the enviromental impact prespective (Hasan, 1999; Hasan *et al.*, 2008; Kneifel, 2010 and Beccali *et al.*, 2013).

Achieving the desired level of energy efficiency in any economy is a cross cutting issue that depends upon the involvement of all sectors. In the case of the built environment, energy efficiency achievements relies greatly on designing the right strategies according to the local content, and have them widely known for its effective implementation. Discussion on necessary course of action and policies that involves the government, private sector and individuals participation have been reported by Clarke *et al*. (2008) and Dixon *et al*. (2010). Some of them have also been discussed in this thesis under the topic: current practices in building energy use and optimization. It is in this line, that the following paragraph discusses some strategies, that can be implemented while projecting an energy efficient house.

2.7.1. Building orientation

The orientation of the building is one of the most important elements that influence greatly its thermal performance (Pacheco *et al*., 2012 and Rodriguez-Ubinas *et al.*, 20014b). A well oriented building can save significant amount of energy needed for conditioning indoor temperatures (Rodriguez-Ubinas *et al.*, 2014a). The sun and wind are natural elements with significant heat and cooling component, respectively. Therefore, building up a house taking into consideration their movements is crucial while designing an efficient house.

A well oriented house is that, which allows the sun’s radiation to enter in the house during winter, and expels it during summer. Moreover, it should also expose or protect the building envelope from the wind (Rodriguez-Ubinas *et al.* 20014b). In hot and humid countries, ideally, the buildings long façade should face opposite direction from that where the sun raises, to avoid long exposure time to the solar radiation during the day. Meaning that, the building longer sides should be oriented toward the north and south directions, with the shorter side toward the east and west directions (Pacheco *et al*., 2012).

2.7.2. Insulation

Insulation is not a new concept in developed countries, where nearly all new and some existing buildings were built taking into account this element. On the other hand, in developing countries such as Mozambique, even though the concept is broadly known, its adoption is still in its infancy, allegedly because of its high acquisition costs, and also because people are resistant to change. Since it is a relatively new concept, people are usually afraid of trying, unless it is been broadly deployed.

Considering that it is through the roof where most of the heat is gained and lost, them this part of the house should be well thermally insulated. Additionally, floor and external walls can also be thermal insulated (Pacheco *et al*., 2012). The combination of these measures can reduce significantly the house's energy demand for heating and cooling (Rodriguez-Ubinas *et al.* 20014b). Therefore, it is important to incorporate the element of insulation while designing energy efficient houses.

2.7.3. Ventilation

The use of mechanical ventilation to control the thermal comfort and indoor atmosphere has been increasing dramatically all across the world. However, due to its associated energy cost, lately, measures to lessen its impact on the household's energy bills have been increasing considerably. Studies conducted by Kim and Park (2010) and Lee and Gao (2011) suggest natural ventilation to reduce the households energy consumption. Moreover, Whang and Kim (2014) concur and stipulate that indoor environment could be improved through a proper size and location of windows and door of the building, taking into account wind speed and direction.

2.7.4. Landscaping

Proper house landscape makes it possible to elevate the quality of the indoor atmosphere during all seasons. For example, planting trees not only gives the sense of fresh air, but can also provide shade to the house, considering these trees are well positioned, especially planting deciduous trees that shade the west side enables the house to have a cooling effect on hot summer afternoons, and also enables solar radiation penetration during the winter (Akbari, 2002).

2.7.5. Use of heat absorbing materials

The materials that are used to build the house, which constitute the building envelope dictate the complementary need for heat or cooling that the house will require to providing satisfactory thermal comfort conditions for its tenants. Dense materials such as stone, concrete and brick have high thermal mass, which is the ability to absorb and store heat. They heat up and cool down very slowly, which means they take longer to heat up before beginning to cool down (Rodriguez-Ubinas *et al.*, 2014a).

According to Rodriguez-Ubinas *et al.* (2014a), provided that the house is well ventilated at nights, a house built with high thermal material is preferable because it keeps the house cool during summer, thus reducing the need of mechanical conditioning. However, it is important to ensure that if these materials are used in external walls then a proper insulation that guarantees separation between external from internal wall surfaces should be considered (Pacheco *et al*., 2012).

When it comes to selecting the suitable colors for the house, they usually depend upon the season. Ideally, during summer lighter colors should be used because they reflect the sun's radiation, while in winter dark colors are the most suitable since they will absorb solar heat, therefore improving the heat storage of the house.

2.7.6. Window placement, sizing and shading

Windows are one of the house's elements that affect the house energy consumption. They have several functionalities, ranging from, trapping or collecting solar radiation, ventilate the house as well as providing cross ventilation. Around 25% of the heat gained in a typical house is lost through windows (DOE, 2000). The use of shades has great impact on controlling heat to entering the house. However, most of the shading devices such as roller shades and overhangs, as agued by Pacheco *et al*. (2012), are fixed and remain in the same position. Therefore, the best shading device should be that, which responds to the household needs according to the season of the year. The authors suggest the use of long projecting horizontal overhangs that can be adjusted according to the need of households. Additionally, proper glazing should be considered while designing an energy-efficient house. In hot humid climate, Pacheco *et al*. (2012) suggest a double clear glazing.

2.7.7. Use of energy efficient appliances

Appliances contribute significantly to the amount of energy consumed by households during the building lifetime. Therefore, using energy efficient appliances for heat, ventilation, air conditioning, lighting, water heating and other appliances is crucial to reduce the total energy consumed by the households.

The deployment of efficient appliances has been one of the top strategies to reduce energy demand worldwide. Energy efficient appliances provide the same service with lesser energy input, which explains why this policy has been proved to be efficient in countries where it is being implemented. Due to its quick win characteristic, the replacement of incandescent light with fluorescent ones has been one of the most implemented energy efficient policies regarding the promotion of energy efficient appliances worldwide. According to Menanteau and Lafebvre (2000), compact fluorescent lights not only use less energy with the same level of illumination, but also last longer (from 5 to 10 times longer) when compared to incandescent lights.

Chapter 3: Methodology

This chapter discusses the methodology used to design the research, for the data collection and data processing. First, it presents the research design and details of the methods used to meet the research objectives. Then, a description of the data collection procedures and data processing methodology is outlined. The following chapter reports the results from the survey and discusses the main findings.

3.1. Research Design

This section describes the methods used to meet the objectives of this research. The research is based on a descriptive study, whereby a household's energy consumption pattern and its main drivers are described. The research design type is comparative study of economic performance of conventional and energy-efficient buildings, which was carried out in Maputo. Since the case study area is relatively broad, a survey was conducted within given time and financial constraints, which made it possible to structure a sample accordingly.

In order to achieve this, the investigation started by looking at the global status of energy and its main related issues. It is pointed out that energy efficiency in building, principally in residential buildings, is a way to overcome some of the energy related problems that are currently affecting the world. The selection of energy efficiency was based on an extensive review of literature in the available studies published by many academic journals that indicate this measure to be one of the most cost-effective (Beccali *et al.*, 2013; Marszal *et al.*, 2011 and Wand *et al.*, 2005).

An extensive literature review of energy efficient legislation that is being implemented in different countries was carried out, in order to assess the available strategies that are there to enhance energy efficiency within the residential sector. In addition, an investigation was carried out to identify parameters and characteristics that distinguish a conventional building from an energy efficient building. Then a questionnaire was designed to capture all relevant data to answer questions including, but not limited to: the main energy end use within households in Maputo, sources and cost of energy as well as type of the house.

3.2. Data Collection

3.2.1 Location

This research assesses the economic performance of conventional and energy efficient measures in the residential buildings in Maputo city. The reason why Maputo was chosen is due to the fact that so far the city has captured the bulk of investment in new buildings, either public or private, also because the majority of civil construction companies are based in Maputo. In addition to this, all ministries that participate in the energy and building sectors are located in Maputo, which would facilitate data collection.

According to the municipality of Maputo City, there are seven (7) municipal districts, namely, *KaMpfumo*, *KaNhlamankulu*, *KaMaxakeni*, *KaMavota*, *KaMubukwana*, *KaTembe* and *KaNyaca*. There are different social groups living in these areas, however, for this research proposes two different groups were considered, the high and middle income households. The reason for this choice was because these two groups are considered by EDM (2013) to use many electrical appliances due to their typical life standard in comparison to the low income households, which according to Cuvilas *et al*., (2010) rely mostly on traditional energy carriers, which are not compatible with electrical appliances**.** Therefore, this research focused on the municipality district of *KaMpumo*, as, according to INE (2007) and CMM (2010), it bears most of the high and middle income households, in relation of all other municipal districts that comprises the city of Maputo.

According to the city planners, the municipality district of *KaMpumo* consists of 11 neighborhoods, namely, *Central A*, *Central B*, *Central C*, *Alto Maé A*, *Alto Maé B*, *Malhangalene A*, *Malhangalene B*, *PolanaCimento A*, *Polana Cimento B*, *Coop* and *Sommerchield* (CMM, 2010). The *KaMpumo* municipal district comprises 106,250 people, representing 27,023 households.

3.2.2 Sampling

Due the time and financial constraints to cover all 27,023 households, the sample size was determined according to the following formula (Calmorin and Calmorin, (2007), p.238).

$$S_s = \frac{NV + \left[(S_e)^2\ (1-p)\right]}{nS_e + \left[(V)^2\ p(1-p)\right]} \qquad (3.1)$$

Where**:**

N = Total number of population

n = number of households in each neighborhood

P = Larger possible proportion (0.5)

V = Standard value (2.58) of 1 percent level of probability with 99 percent reliability

S_e = Sampling error (0.01)

S_s= Sample size

The sample size of S_s= 256 households, was calculated considering the universe of 27,023 households that are there in the *KaMpumo* municipality district, thus, this universe is not evenly distributed in all neighborhood. Which means that each neighborhood have different population size, therefore, in order to calculate the sample size for each neighborhood from the *KaMpumo* municipality district, the total number of the population was dived by number of the households in each neighborhood and then multiplied by the sample size. Moreover, the sampling design and technique that this research will be considered is the random sampling. Table 3.1 indicates the number of households that were subject of the questionnaire.

Table 3.1: Sample size.

Order	Neighborhood	Number of households	Sample Size
1	Central A	2,548	24
2	Central B	2,862	27
3	Central C	2,158	20
4	Alto Maé A	2,053	19
5	Alto Maé B	2,959	28
6	Malhangalene A	1,725	16
7	Malhangalene B	4,051	38
8	Polana Cimento A	2,408	23
9	Polana Cimento B	2,370	22
10	Coop	1,417	13
11	Sommerchield	2,472	23
Total	11	27,023	253

To gather all the necessary data, this study utilized instruments such as desk-top surveys, questionnaires and interviews. Questionnaires were used to gather information from the selected households regarding their energy consumption levels, source of energy, types of appliances, initial investment costs to build the house, maintenance costs, floor area of the house, number of rooms among others. Detailed information is provided in the questionnaire in appendix. Literature review was used to access other information that the questionnaire did not cover, such as discount rate.

To gather information about energy efficient practices in the civil construction sector from Mozambique four distinctive companies were interviewed, namely, companies A, B, C and D. The results provided by the questionnaire combined with information provided by the city planners and commercial banks made it possible to calculate the life cycle cost of r conventional and energy efficient buildings.

3.3 Data processing

3.3.1 Economic assessment

The aim of this study was to assess the potential cost and benefits of implementing energy efficient measures in residential buildings. Incorporating measures that are conducive to efficient energy use in residential buildings requires investments in material and human resources. Early studies carried out by Westphal and Lamberts (2005), Ramesh *et al.* (2010), Cabeza *et al*. (2013), and Mata *et al*. (2013) point out different approaches that could be considered in buildings to improve their efficiency in terms of energy consumption, and several models have been designed in this regard. Thus, these studies main focus is on environmental issues rather than the cost perspective.

In fact, most of the studies are based on the Life Cycle Assessment (LCA), and only a few investigate the Life Cycle Cost Analysis (LCCA) perspective. Previous studies on LCCA that focus on the minimization of life cycle cost of the building envelope design with the adoption of energy efficient measures include the work reported by Arpke and Hutzler (2005), Fuller (2005) and Lutz *et al.* (2006). This study considered some of the indicators used by these authors, such as: (1) Payback period (2) cost of conserved energy and (2) Life Cycle Cost Analysis (LCCA). However, it is important to note that the emphasis was on LCCA, because it captures the total cost of the building over its lifetime.

This research mainly focused on the LCCA because it is a technique that enables the determination of the total cost of owning and operating a facility over a specific period of time. LCCA can be defined as the total discounted dollar cost of owning, operating, maintaining, and disposing of a building system over its lifespan. With this indicator, the expectations are that a real picture of the financial benefits that may result from owning an energy efficient building could be verified.

The payback indicator would allow the calculation of the time frame that is needed to recover the investment in efficient practices. This indicator enables users, investors and constructors to have an overview of how much time an investment decision made today may need to be recovered over the time that the building will be operating. The premise that was considered in this study is that there are two alternatives to build a house: one is built in the conventional manner, which means, it does not take into account energy efficient measures (the base case), and the other one considers the most applicable and practicable energy efficient parameters (energy efficient option).

If households are to be convinced to change their energy consumption patterns as well as make better decisions while considering building a house in terms of the costs that each decision will require throughout their life time, evaluation of the cost of energy efficiency is of the utmost importance, as it provides to all the necessary information about operational costs. This indicator enables the comparison between the costs that a conventional building is associated with those that an energy efficient building would otherwise incur.

"The Life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life" [White and Ostwald, (1976), p.39]. Thus, it represents not only the acquisition cost, but also all subsequent costs expected for operating and maintaining the building, as well as the residual value and any other quantifiable benefits (Browns and Yanuck, 1985). LCC is an economic tool that makes it possible the comparison between different alternative products or designs that provides similar services to the user, its calculation process enables decision markers to select the best solution, which presents the lower overall cost besed on existing information (Lutz *et al.,* 2006).

3.3.2 Model for calculation of Life Cycle Cost

In this study, the models suggested by Fuller and Petersen (1996) combined with that from Lutz *et al.* (2006) were used to calculate the LCC present value for annually recuring uniform amounts and present value for annually recuring non-uniform amounts, respectively.

a) Present Value of Initial Investiment

The present value for the initial investment is equal to the amount of the initial investment, since it is made at exactly the same time when the future costs are being discounted, and it is comprised of the initial costs for building or buying and house and the acquisition of the appliances

b) Present Value of Operanting Costs

i) For annual recurring uniform amounts

$$\mathrm{PV} = \mathrm{C}_{aoc} \sum_{t=0}^{n} \frac{1}{(1+d)^{t}} = \mathrm{C}_{aoc} \left[\frac{(1+d)^{n}-1}{d(1+d)^{n}}\right] \tag{3.2}$$

ii) For annual recurring non-unifirm amounts

$$\mathrm{PV} = \mathrm{C}_{aoc} \sum_{t=1}^{n} \left(\frac{1+e}{1+d}\right)^{t} = \mathrm{C}_{aoc} \left(\frac{1+e}{d-e}\right)\left[1 - \left(\frac{1+e}{1+d}\right)^{n}\right] \tag{3.3}$$

Where:

PV= present value

C_{aoc}= annual operating cost

e= escalation rate

d=is the discount rate

n= building life time

t=period of time that the costs will be occurring

To compute the PV for appliance replacement, annual operating cost (C_{aoc}) in Eq.(3.3) was replaced by the appliance replacement cost (C_{arc}).

c) Present Value of Maintenance Costs

$$\mathrm{PV} = \mathrm{C}_{amc} \sum_{t=1}^{n} \left(\frac{1+e}{1+d}\right)^{t} = \mathrm{C}_{amc} \left(\frac{1+e}{d-e}\right)\left[1 - \left(\frac{1+e}{1+d}\right)^{n}\right] \tag{3.4}$$

Where:

C_{amc}= annual maintenance cost

e= escalation rate

d= discount rate

n= building life time

t= period of time that the costs will be occurring

d) Present value of the Residual Value

$$PV = \frac{C_{rv}}{(1+d)^n} \quad (3.5)$$

Where:

C_{rv}=residual value

d=discount rate

n=building life time

Sharma *et al.* (2011) and Beccali *et al.* (2013) indicate that, it is during the operating phase when a residential building consumes the bulk of energy that the building requires throughout its life time, ranging from 70-90%. Furthermore, the demolishment stage does not go beyond the figure of 2%, and the remaining is consumed during the building erecting phase. It is in this perspective that this research main focus was only on the operational stage, and construction phase. However, during the construction phase, the study focused mainly on the initial investment costs, which have the energy costs already embodied. Input data to the model is provided in Appendix D.

3.3.3 Statistical analysis

A descriptive statistical technique was used to analyze the collected data on the households' energy consumption patterns, main type of appliances being used as well as the building main features. There is lack of green and energy efficient building, in Mozambique, most of the building either existing or new, follow the construction idea that the country inherited from Portugal, which is the country that colonized Mozambique, based on the idea of lasting for long, which includes basically a strong structure made of cement and stone. This means that locally, there is no benchmark case, which could be used to compare its performance to those that are not energy efficient.

Therefore, in order to overcome this barrier, hypothetical prototypes that incorporate relevant energy efficient indicators, were designed using ARCHICAD software, and information concerned with energy consumption was provided by electro-technicians from EDM. These designs were compared to the base case scenario, which was obtained from the results of the questionnaire. The base case scenario was drawn by calculating the average size, sources of energy, and energy consumption of the surveyed houses.

In order to analyze the potential outcomes from different energy efficiency alternatives a sensitivity analysis was performed and its main focus was on three key components, namely:

i) Changes in the building envelope;
ii) Use of energy efficient appliances;
iii) Changes in the building envelope and energy efficient appliances.

To evaluate the cost/benefits of each of the hypothetical cases, tools, such as, LCCA and cost of conserved energy were used. Its results were compared to those of the base case scenario.

Chapter 4: Results and Discussion

The aim of this research was to assess the economic feasibility of energy efficient measures within the Mozambican residential building, and for that, the case study was carried in Maputo, the country's capital city. In this perspective, Chapter 2 looks at the state of the art of work that has been done to assess the impact of the use of energy efficient measures and strategies to reduce the residential sector final energy consumption. Chapter 3 details the methodology used to answer the overall and specific objectives of the thesis. The findings of the survey are presented and discussed in detail in this chapter.

4.1. General Data

The data was collected from a survey made in the Municipality District of *KaMpfumo* located in the City of Maputo, based on the questionnaire in Appendix A, which includes the original questionnaire and the Portuguese translated version. Theoretically, the sample size determined was of 253 households, however, because of difficulties encountered in accessing some of the houses located in the *Sommershield* neighborhood, the actual sample size used was 233 houses, which resulted in what Table 4.1 indicates (See detailed data in Appendix B).

Table 4.1: Number of the surveyed houses and respective percentage.

Order	Neighborhood	Surveyed houses	Relative percentage
1	Malhangalene B	38	16
2	Alto Maé B	28	12
3	Central B	27	12
4	Central A	24	10
5	Polana Cimento A	23	10
6	Polana Cimento B	22	9
7	Central C	20	9
8	Alto Maé A	19	8
9	Malhangalene A	16	7
10	Coop	13	6
11	Sommershield	03	1
Total	11	233	100

Table 4.1 shows that *Malhangalene B* exhibits the largest number of households that were covered in this survey, which add up to about 16% of total houses, followed by *Alto Maé B* with 12%. It is important to note that, *Coop* should have been the neighborhood with least surveyed

households. However, due to difficulties in accessing the houses in *Sommershield*, this neighborhood is now the one with the least percentage.

According to Figure 4.1, the ownership status of the surveyed houses is that of the 233 houses, 57% are individually owned, 36% are rented and the remaining 7% are qualified into other categories This indicates that they are either owned by private companies, parastatals or the government. It should be noted that, the bulk of individually-owned houses are mostly found in *Malhangalene B*. On the other hand, *Central B* has the highest number of rented houses. Furthermore, *Coop* has most of the houses that fall under other categories.

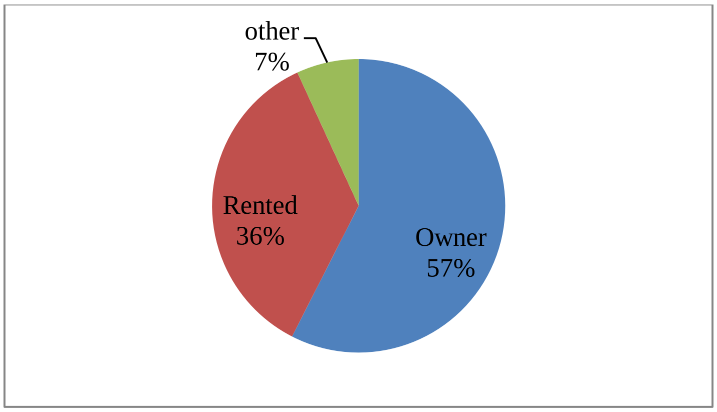

Figure 4. 1 : Ownership status of the surveyed houses

Usually, people who live in their own houses, tend to care about its maintenance in order to preserve its habitability qualities throughout its lifetime (Rohe, *et al.*, 2013). Additionally, the likelihood of them knowing not only the maintaining costs, but also acquisition prices of the houses, is relatively high in comparison to people who rent or are under other categories. This could explain why some households claim to be unaware of these costs. Despite the fact that investments in energy efficient measures being unattractive in comparison to conventional measures, their long term benefits are undeniable. In the case of rented houses, there is one more phenomenon that can be observed, where the occupants may desire to have their energy bills reduced by incorporating energy efficient elements in the building envelope. However, contractual arrangements between landlord and tenants may inhibit these investments.

Figure 4.2 indicates that approximately 45% of the households believe that the houses they are living in were built for more than 51 years, and almost 27% of the households have no idea about when the house was built. Moreover, 11% of the households think that their houses are between 41 and 50 years old. Meaning that, the bulk of the surveyed houses were built prior to the country's independence in 1975. Houses with less than five years and those built between 6 and 10 years shares the same percentage of 1%. Similarly, houses built between 11 and 20 years and between 21 and 30 years shares the same percentage of 4% each. Finally, houses built between 31 and 40 years represent 6% of the total surveyed houses. It is inferred that most of the houses surveyed in this study are older than 51 years. Meaning that, most of the surveyed houses are old enough to be demolished or in a need of profound rehabilitation to be re-used, considering that the study assumption is that the buildings last for no more than 50 years, which is the building useful life. In addition, from the surveyed houses, it was noted that some of the buildings where considerably degraded, and for those that were in good condition, they underwent considerable re-structuring in recent years.

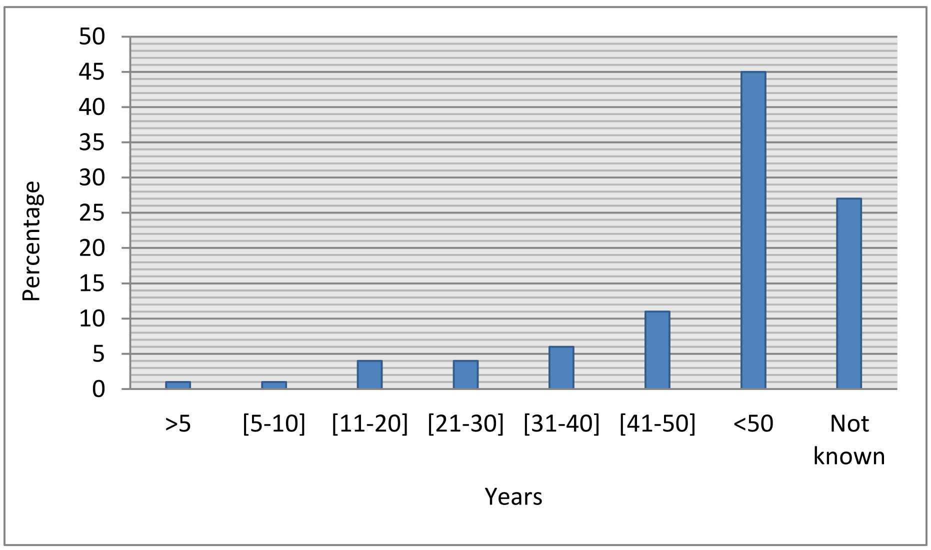

Figure 4.2: Age of the surveyed houses.

The findings from the survey show that, there are three different types of houses, conventional houses, apartment block and part of commercial building. These houses are comprised of seven different sub-types of houses, namely, type 2, 3, 4 and 5 conventional houses, type 1, 2, 3 and 4 apartment blocks and a house that qualified as part of a commercial building. The number of the house type implies its relative number of bedrooms, meaning that for example: a type 1 apartment block and type 1 conventional house have 1 bedroom each. However, most of the surveyed houses are type 3 apartment block, which represents 43% of the 233 houses. The type 2 apartment blocks constitutes 26% followed by type 3 and 2 conventional houses with percentages of 12% and 7%, respectively. The other house type has minor representation, for instance, apartment block and conventional houses of type 4 have a percentage of 5% and 3%, respectively. The same was found for the type 1 apartment block with a percentage of 2%. There was only 1 house for both, type 5 conventional houses and part of a commercial a building that resulted in 0% of the relative percentage.

The reason why there is a plethora of apartment blocks is because the survey was conducted in the city of Maputo, where there are many high rising buildings and a few conventional houses. This is similar to many Capital cities across the world where the preferable house types are high rising buildings (Gottmann, 1966). It is crucial to note that, this data was used to design energy efficient houses, meaning that the type 2 and 3 houses were the two samples that were considered while developing the energy efficiency design. The proposed energy efficient designs were types 2 and 3 conventional houses with single floor.

The findings from the survey indicate that 46% of the targeted houses follow an East-West orientation according the long axis of the building. This does not correlate with what the principles of good orientation stipulates (DOE, 2000). For instance, in hot humid climate that characterizes Mozambique, North-South orientation, in relation to building long axis, is the one that when combined to other energy efficiency features would contribute in reducing or even eliminate auxiliary cooling or heating requirements, thus reducing energy expenditures of the households. Additionally, good orientation can also help improve indoor comfort levels for the households (DOE, 2000).

From the interview with architects from company A, they also claimed that it is important to avoid direct sun radiation, and this can be accomplished not only with good orientation but also by using trees and adjoining buildings to shade the exposed facades of the houses. Moreover, they also said that new technologies allow the use of architectural elements for solar protection, such as vertical and horizontal flaps as well as adjacent windows that allows the air to flow inside the house.

The householders when asked about the current cost of the house, only 42% knows about the actual cost of the houses they are living in, and 58% of the households do not know. The same was found for the annual maintenance cost estimation, where the majority of the surveyed households, around 57%, did not know about the annual maintenance cost, some because they do not keep track of these expenditures and others because they do not do it at all, unless it is an immediate repair. Table 4.2 demonstrates the average cost of different type of houses and the equivalent annual maintenance costs. Judging from what the table depicts, there is no linearity between the house types and its relative current acquisition costs. For instance, one could expect that a type 2 apartment block to be cheaper than a type 3 apartment block, which is not the case in this situation. The most probable answer to these incongruences is that different neighborhoods have different prices. Moreover, there is also the matter of price speculations, whereby, landlords tend to over rate or under rate the market value of their houses. Additionally, from the surveyed households who live in conventional house type 5 claims not knowing the acquisition and annual maintenance costs of their houses. In the case of tenants of the part of commercial building, despite the fact of knowing the house acquisition costs, they do not know about its relative maintenance costs.

Table 4.2: Average of the houses acquisition and annual maintenance costs (current costs).

House type	House acquisition costs (MT)	Annual maintenance costs (MT)
Conventional house type 2	1,451,786.00	10,714.00
Conventional house type 3	4,502,857.00	28,762.00
Conventional house type 4	4,255,000.00	38,750.00
Conventional house type 5	-	-
Apartment block type 1	1,500,000.00	20,000.00
Apartment block type 2	3,035,000.00	13,244.00
Apartment block type 3	2,707,500.00	23,567.00
Apartment block type 4	3,750,000.00	89,666.00
Part of a commercial building	2,000,000.00	-

It was necessary to estimate the acquisition and maintenance costs for the LCC calculation. As explained in Chapter 1, under the section 1.4, it was mentioned that apartment blocks bears specific characteristics, which to meet one of the propose of the study of suggesting the energy efficient design, would be unpractical since the suggested design should meet the main features of this type buildings. Therefore, to overcome this limitation, the collected data from the apartment blocks where merged with that from the equivalent conventional houses (houses comprises with single floor). The resulting values where considered to be the benchmark of each house type according to their number of bedrooms, these benchmark are from now on designated as Type 2 house and Type 3 house.

To calculate the LCC of the houses, it was necessary to estimate the initial investment for acquiring the appliances. This was done by investing the costs to acquire them in the Mozambican market, which resulted in the estimated costs presented in Table 4.3(For more details, see data in Appendix D). During the building lifespan, appliances are replaced, which implies a recurrent cost during the period of time when the replacement occurs. This thesis considers an average of 10 years recurrent appliances replacement throughout the building lifespan, which according to Cooper (2004) was the average time considered to be "reasonable" by the households that were subjected to his study. Besides the appliances initial investment, the household will replace them for 4 more times. Table 4.3 indicates the average costs for acquiring the house, appliances and maintaining those houses.

Table 4.3: Average costs for house acquisition and annual maintenance costs for LCC calculation.

House type	Average costs for house acquisition (MT)	Appliances initial investment cost (MT)	Average costs for annual maintenance (MT)
Type 2 House	2,243,393.00	121,166.00	11,979.00
Type 3 House	3,605,179.00	147,000.00	26,164.00

Not only was the collection of data regarding the house type in all targeted households important and so was the collecting data in respect to the household's floor area. This floor area data was taken into consideration while designing the energy efficient houses. In this view, the survey shows that, on average the floor area for types 1 and 2 apartment blocks is 96.25m^2 and 111.61m^2, respectively. Moreover, type 2 conventional houses' floor area is 106.11m^2 and for the case of type 3 conventional houses the floor area is approximately 116.40m^2. Table 4.4 demonstrates the floor area of each house type including compartments number according to each house type.

Table 4.4: Average of the floor area and number of compartments according to each house type.

Floor area/number of compartments	Conventional type 2	Apartment block type 2	Conventional type 3	Apartment block type 3
Floor area (m^2)	106.11	96.25	116.40	111.61
Porch	1.30	1.60	1.83	1.82
Bedroom	2.00	2.00	3.00	3.00
Bathroom	1.53	1.38	1.59	1.69
Kitchen	1.00	1.00	1.11	1.00
Corridor	1.18	1.13	1.35	1.19
Living room	1.00	1.00	1.17	1.01
Dining room	1.00	1.00	1.04	1.00
Office	1.00	1.00	1.00	1.00
Other	-	1.00	1.00	1.50

To estimate the number of compartments for the energy efficient design, this study considered the average of the compartments in type 2 conventional house and type 2 apartment blocks. Similarly, an average for type 3 conventional houses and type 3 apartment blocks was also calculated. Table 4.5 shows the average number of compartments as well as the average of the floor area of the houses that was considered for energy efficient designs.

Table 4.5: Average of the floor area and number of compartments to be considered for the proposed energy efficient houses.

Floor area/number of compartments	Type 2	Type 3
Floor area (m^2)	101.00	114.00
Porch	2.00	2.00
Bedroom	2.00	3.00
Bathroom	2.00	2.00
Kitchen	1.00	1.00
Corridor	1.00	1.00
Living room	1.00	1.00
Dining room	1.00	1.00
Office	1.00	1.00
Other	1.00	1.00

4.2. Energy Consumption Data

During the process of data collection, questions to access household energy consumption patterns, such as sources of energy, type of existing appliances as well as the energy bill of the households were asked. With the given answers it was possible to identify the sources of energy of the households, the amount of money spent monthly, and the annual average expenditure. Surprisingly, nearly all households claim to consume almost the same quantity of energy monthly regardless of the season.

With respect to the sources of energy, it was possible to determine that 100% of the targeted households use electricity to meet their energy needs, and almost 91% of them complement their energy need with LPG, which is used mostly for cooking and water heating. Furthermore, charcoal is also being used by nearly 52% of the surveyed families.

Malhangalene B, from all 11 neighborhood surveyed, is where almost all households supplements electricity with LPG and charcoal. On the other hand, none of the households in *Central C* uses charcoal as part of their energy source. This can be justified by the fact that this area is inhabited by high income households, who usually use cleaner energy sources to meet their requirements. Moreover, it was also possible to note that none of the surveyed households uses other sources of energy such as Diesel oil-generator, coal, paraffin and firewood. Only one, out of the 233 households, owns an installed solar panel, which is only used when there is no electricity supply (See data in Appendix B).

On average, all households have at least one of the following appliances: freezers, television, kettle, ironing machine, DVD, microwave, refrigerator, fans, stoves and computer. It is worth noticing that, although computers did not appear in the questionnaire, it was one of the appliances that appeared the most as other appliances owned by the households. Its exclusion was due to its minor contribution reported in the survey made by EDM (2012a). Despite being rare, some households indicated to own toasters, vacuum machine, electric shower, washing machine, water pumping machines and sewing machines. Moreover, only a couple of the surveyed households own sound amplifiers and radios.

While appliances such as, electric geysers and air conditioning are rare, mostly because the households cannot afford them, some are not capable to cope with the required maintenance routine as well as its allegedly high energy consumption, electric space heaters are also rare, but the reason is different, in their case they are considered to be superfluous due to the local weather conditions.

When looking at the number of lights, generally the number of compartments dictates the household real need. It was also noticed that the majority of the households mixes the types of lights, not only do they use compact fluorescent but also incandescent lights, which is an indication of shifting to more efficient lights (fluorescent lights). To estimate the number of appliances tk8hat each house should have, the average of existing appliances of a type 2 conventional houses and type 2 apartment blocks was calculated, and the same was done for the type 3 conventional houses and type 3 apartment blocks. Table 4.6 illustrates the number of appliance for the energy efficient house according to the type of house.

Table 4.6: Average number of appliance for the energy efficient house according to the type of house.

Type of appliances	Number of appliances					
	A1*	A2*	A3*	A4*	A5*	A6*
Freezers	1.05	1.11	1.00	1.25	1.08	1.00
CFL	6.62	7.81	11	8.73	8.03	12
Incandescent	3.83	4.98	0	6.97	5.48	0
Televisions	1.94	1.90	2.00	2.63	2.40	3.00
Electric Geysers	1.00	1.03	1.00	1.48	1.13	1.00
Stoves	1.14	1.14	1.00	1.25	1.07	1.00
Kettles	1.08	1.04	1.00	1.21	1.06	1.00
Ironing Machine	1.30	1.13	1.00	1.28	1.18	1.00
DVD	1.22	1.08	1.00	1.57	1.16	1.00
Air conditioning	1.00	1.53	1.00	2.13	1.93	2.00
Fans	1.50	1.82	2.00	1.84	1.78	2.00
Microwave	1.00	1.01	1.00	1.17	1.01	1.00
Refrigerator	1.00	1.05	1.00	1.17	1.05	1.00
Sound amplifiers	1.00	1.00	1.00	1.07	1.53	1.00
Radios	1.06	1.08	1.00	1.21	1.01	1.00
Space heaters	1.00	1.00	1.00	1.00	1.00	1.00
Other appliances						
Computers	1.16	1.03	1.00	1.44	1.22	1.00
Toasters	1.33	1.47	1.00	1.29	1.05	1.00

*Note: A1=Conventional type 2, A2=Apartment block type 2, A3=Average for the efficient design –type 2 house, A4=Conventional type 3, A5=Apartment block type 3, A6=Average for the efficient design –type 3 house.

The degree to which certain appliances consume energy depends greatly on the power capacity, usually measured in watts (W). It was from this point of view that accessing the power capacity of the appliances used by the household was important; not only to determine if they could be qualified as efficient or inefficient but also to determine which appliances contribute the most for the monthly energy expenditure of the families.

The survey indicates that on average, the appliances are relatively young, approximately 4 years old, except for freezers and refrigerators, which are nearly 6 and 6.5 years old, respectively. These two appliances are the ones that remain operational for long hours, almost 24 hours a day (See data in Appendix B). Furthermore, households that own electric geysers and air conditioners, tend to keep them operational for over thirteen and eight hours a day, respectively. Due to their relatively high power capacity, these appliances contribute significantly to the household's energy burden. In case of television, and compact fluorescent lights, which are owned by almost all targeted families, the average time that these appliances are kept operational is of approximately nine hours a day. Contrary to electric geysers and air conditioners, these appliances do not have high impact on the total energy demand, due to their relatively low power capacity.

Stoves are by far, the appliance that has high power capacity, with an average of 2,774.50W, followed by air conditioners, with an average of approximately 2,000.00W. Freezers and refrigerators average of power capacity range from 405.09W and 828.02W, respectively. It is important to note that despite some appliances having high power capacity, their levels of energy consumption will vary according to the time that the appliance remains operational. For instance, a comparison was made between stoves and air conditioners, the conclusion indicated that for those houses that have these appliances, air conditioners are the ones that contribute the most for the household energy bill regardless of its relatively low power capacity, this can be explained by the fact that this appliance usually remains operational for long hours than stoves.

Table 4.7 indicates the average power capacity of the existing appliances in selected types of houses, which will be used as the base to design the energy efficient house. From what the table depicts, it is possible to determine that there is no correlation between the size of house and the appliances power capacity, this could be because the houses are quite similar except for the number of rooms.

Table 4.7: Average of appliance power capacity for selected type of houses.

Type of appliances	B1* (W)	B2* (W)	Average (W)	B3* (W)	B4* (W)	Average (W)
Freezers	407.86	347.42	378	304.95	294.18	300
CFL	37.17	40.68	39	30.81	33.01	32
Incandescent	73.89	68.93	71	104.14	68.03	86
Televisions	214.94	176.30	196	155.56	176.54	166
Electric Geysers	1,670.83	1,635.45	1,653	2,843.75	1,870.25	2,357
Stoves	1,593.13	1,920.09	1,757	2,820.83	3,069.44	2,945
Kettles	1,426.53	1,624.80	1,526	1,486.20	1,538.80	1,513
Ironing Machine	1,226.49	1,096.96	1,162	1,028.56	1,254.95	1,142
DVD	24.44	70.95	48	32.33	43.32	38
AC	1,740.00	1,665.63	1,703	1,602.38	1,795.11	1,699
Fans	143.79	95.73	120	98.13	105.23	102
Microwave	1,583.93	1,238.71	1,411	1,248.75	1,273.82	1,261
Refrigerator	397.46	430.71	414	845.06	316.35	581
Sound amplifiers	30.07	73.17	52	72.95	120.00	96
Radios	37.84	60.82	49	71.27	63.46	67
Space heaters	1,000.00	1,740.00	1,370	2,750.00	1,600.00	2,175
Other appliances						-
Computers	423.71	602.40	513	348.52	488.73	419
Toasters	350.00	659.76	505	577.86	868.44	723
Total	12,382.08	13,548.51	12,967.00	16,422.05	14,979.00	15,702.00

*Note: B1=Conventional type 2, B2=Apartment block type 2, B3=Conventional type 3, B4= Apartment block type.

Table 4.8: Annual energy consumption (average) according to each house type.

House type	Energy consumption (kWh)	Cost per kWh (MT)	Annual cost (MT)
Type 2 – Conventional house	17,067.02	3.07	52,395.74
Type 3 – Conventional house	31,713.94	2.92	92,604.70
Type 4 – Conventional house	17,737.47	2.92	51,793.41
Type 5 – Conventional house	33,345.00	2.89	96,367.05
Type 1 – Apartment block	21,565.62	2.89	62,324.64
Type 2 – Apartment block	17,253.75	2.99	51,588.72
Type 3 – Apartment block	27,786.21	2.95	81,969.32
Type 4 – Apartment block	17,193.66	2.99	51,409.03
Part of a commercial building	68,784.30	2.89	198,786.63

Table 4.8 depicts the annual energy consumption according to each house type. It can be seen that, there is no linear relation between the type of the house and the annually amount of money spent by these families. Moreover, the cost per kWh differs in almost all types of houses. The

reason underneath is probably that EDM applies different prices for pre-paid and post-paid electricity. For pre-paid, the price is 3.20MT/kWh, and for post-paid the price is 2.89MT/kWh.

To calculate LCC, this thesis considered the average cost of the two selected house type, then an average of the type 2 conventional houses and type 2 apartment blocks was calculated, and the same was applied to the type 3 conventional houses and type 3 apartment blocks. Table 4.9 illustrates the annual average cost of electricity for type 2 and type 3 houses. The annual average costs of electricity for type 2 and type 3 houses were 51,992.23MT and 87,287.01MT, respectively.

Almost all surveyed households believe that it is important to use energy efficiently. However, only 50% of them implement measures that enable them to have the same service with less energy. These measures range from, use of charcoal or LPG for water heating, use of LPG and charcoal in substitution of electricity for cooking, switching the lights off when not in use, avoid using appliances simultaneously, use of efficient lights, avoidance of using electrical geysers, use of appliances rationally, turning appliances off completely, to leaving them unplugged instandbye mode.

By interviewing architects from company A, claim that, despite their efforts to persuade their clients to consider energy efficient elements while projecting their houses, roughly all of them are resistant to change their previous ideas, which in generally have no energy efficient components. In the few cases were they agree, they tend to disregard the architects suggestion when extra investments are required. However, the architects indicate that, not only the incremental investments are the reasons behind this attitude, so is the lack of awareness of the benefits of energy efficiency buildings and the environmental issues that are behind the global attempt to curb climate change and its negative implications.

When asked about energy related issues that are currently affecting the world, around 82% claim to have no information about it. However, the other 18% mentioned issues such as deforestation, exhaustion of fossil fuels, environmental degradation, global warming, climate change, increase of energy prices, constant blackouts, floods cause by dams constructed for electricity generation, and so on (See data in Appendix B).

4.3. Life cycle cost of buildings

4.3.1. LCC of type 2 and 3 houses

The LLC calculation was made based on the data provided in Table 4.10. For more datail see appendix D.

Table 4.9: Data used to calculate LCC of type 2 and 3 houses.

Data	Type 2 House	Type 3 House
Initial Investment to acquire the house (MT)	2,243,393.00	3,605,179.00
Initial Investment to acquire appliances (MT)	121,160.00	147,000.00
Annual electricity consumption (kWh)	17,160	29,750
Annual maintennance costs (MT)	11,979	26,164
Discount rate (%)	10	10
Energy price escalation rate (%)	9.8	9.8
Maintanance price escalation rate (%)	2.6	2.6
Life time (years)	50	50
Amortization rate (%)	5	5

Based on data provided in Table 4.10 the calculation made resulted in what Table 4.11 indicates. For more details of the calculation see Appendix D, which demonstrates the calculation of the LCC of the two types of houses.

Table 4.10: LCC for type 2 and 3 houses.

Item	Description of cost	Present Value of Type 2 House (MT)	Present Value of Type 3 House (MT)
1	Total Initial Investment (house and appliances)	2,364,558.86	3,752,178.57
2	Total cost for appliances replacement	5,153,761.29	6,252,603.12
3	Operating costs for the first 6 years	309,996.59	521,461.93
4	Operating costs, for the remaining 44 years	897,465.42	1,509,007.56
5	Maintenance costs	160,986.32	351,613.01
6	Residual Value	(1,470.45)	(2,363.05)
7	Total LCC	8,885,298.02	12,384,501.13

While evaluating future cost, it is important to know that there are uncertainities that may happen in the future, in order to lessen its impact on the results, a correctional factor was considered. In order to approximate this cost to the reality, this study used the energy price escalation price suggested by EDM (2012b), which indicates a constant escalation rate of 9.8% from 2015 until 2020 (6 years), and from there on the prices stabilise.

The results found in Table 4.11 suggest that in Mozambique, the total LCC of type 2 house is of about 8,885,298.02MT and for type 3 house, the total cost is of about 12,384,501.13MT. The operating phase for a type 3 house represents nearly 70% of the total cost of owning, operating, and disposing the building, which is almost the same finding for the type 2 houses, that indicates the operating stage is responsible for around 73% of the total cost of the house during its life time.

4.3.2. LCC of the buildings considering energy efficient appliances

The first option considers a house that only improves the energy efficiency of its appliances, and the remaining factors are kept constant. While looking at the average power capacity of the appliances that are being used by the surveyed households, company D, suggested that these appliances could be replaced by their equivalents, which will consume 50% less energy than what the current appliances consume.

This assertion goes along with findings from studies conducted by Granda (2012) and Josephy *et al.* (2014). The former concluded that it is possible to consume between 50 and 60% less electricity with heat pump driers, provided that energy efficiency is enhanced. The latter indicated that a washing machine can consume 70% less electricity when used at lower temperatures. Moreover, according to Topten International Group (2014), there is already available technology on the market that allows improvements over energy consumption of appliances that can reach 60 to 85% efficiency compared to inefficient models being sold and used in many countries.

Table 4.12 indicates the resulting power capacity of the appliances when the recommended improvement is applied according to each type of house. Incandescent lights have been proven by Menanteau and Lafebvre (2000) to be extremely inefficient, and for the LCC calculation they were replaced by an equivalent CFL lights. With these measures, the results indicated a decrease in the annual energy consumption, from the original 17,160.39kWh/year to 7,373.70kWh/year for type 2 house, and from 29,750.08kWh/year to 9,608.40kWh/year for a Type 3 house.

Table 4. 11: Improved energy efficiency of the appliances.

Type of appliance	C1* (W)	C2* (W)	C3* (W)	C4* (W)
Freezers	378	189	300	150
CFL	39	20	32	16
CFL	39	20	32	16
Televisions	196	98	166	83
Electric Geysers	1,653	827	2,357	1179
Stoves	1,757	879	2,945	1473
Kettles	1,526	763	1,513	757
Ironing Machine	1,162	581	1,142	571
DVD	48	24	38	19
AC	1,703	852	1,699	850
Fans	120	60	102	51
Microwave	1,411	706	1,261	631
Refrigerator	414	207	581	291
Sound amplifiers	52	26	96	48
Radios	49	25	67	34
Space heaters	1,370	685	2,175	1088
Other appliances				
Computer	513	257	419	210
Toasters	505	253	723	362

*Note: C1=Average of appliances power capacity (W) of type 2 house, C2=Average of appliances power capacity (W) for type 2 house, considering improvement of 50%, C3=Average of appliances power capacity (W) of type 3 house, C4=Average of appliances power capacity (W) for type 3 house, considering improvement of 50%.

Table 4.12: LCC for type 2 and 3 houses - Considering 50% improvement of the appliances.

Item	Description of cost	Present Value of Type 2 House (MT)	Present Value of Type 3 House (MT)
1	Total Initial Investment (house and appliances)	2,425,141.86	3,825,678.57
2	Total cost for appliances replacement	7,731,602.46	9,378,904.67
3	Operating costs for the first 6 years	133,203.38	168,416.85
4	Operating costs, for the remaining 44 years	385,634.64	487,365.02
5	Maintenance costs	160,986.32	351,613.01
6	Residual Value	(1,470.45)	(2,363.05)
7	Total LCC in MT	10,835,098.19	14,210,780.40

The calculation of LCC indicated in Table 4.13 indicates that, considering that the households use appliances that are 50% more energy efficient than those that they have been using, the LCC increases by 18% and 13% for type 2 and type 3 houses, respectively. Despite the relative decrease of energy costs the overall cost increases due to the increased cost of acquiring efficient appliances. It should be noted that, the estimation of appliances initial investments was done by assuming that due to their energy efficiency improvements the cost was aggravated by a factor of

50%. In this assumption, no change is made to the building envelope. For more details of the LCC calculation, see Appendix G.

4.3.3. Building LCC considering building energy efficient elements

The following sensitivity analysis focuses on the use of building energy efficient elements. As argued by company A, the adoption of elements such as roof and wall insulations, cross ventilation, double clear glazing, well oriented house as well as the use of window overhangs the actual energy consumption can be reduced significantly while providing the house occupants with the required indoor comfort. Furthermore, they claim that the use of these elements eliminates or reduce significantly the need for critical appliances such as electric heater and air conditioning, respectively. Despite the existence of other energy efficiency strategies that can be adopted while promoting an energy efficient building (some of them have been discussed within this thesis) only elements suggested by companies A, B and D are considered in this discussion.

The energy efficient design suggested by company A is presented in Appendix H, which indicates the house plan for types 2 and 3. In Appendices 5 and 6, the relative investment costs estimated by company B are indicated. Table 4.14 illustrates the total energy consumption of the type 2 and 3 houses when appliances operational time is adjusted, without taking into account the use of energy efficient appliances. However, adjustment of appliances operational time were considered, for instance, the surveyed houses on average kept their lights on for 9 hours, however considering energy efficient practices, the suggested time by company A, is of 5 hours. The use of electric heaters was eliminated, mostly because the Mozambican weather condition allows this elimination, considering that the houses are well oriented and insulated, as indicated by company A.

The running time ratio for freezers and refrigerators was determined according to the findings from the study carried out by Homes and Melo (2009). They concluded that the runtime of these appliances when controls for thermostat and damper are at maximum level is a factor of 0.66. This means that these appliances run for about 66% of the day 16 hours per day. This factor was used to correct the data from the survey, because almost all respondents indicated that refrigerators and freezers run for 24 hours, which is not the case. The same factor was also used for the proposed energy efficient houses.

The study considered the maximum factor because Mozambique is a hot and humid country which makes these appliances to run for longer periods when compared to cold environments. Borges *et al*. (2011) state that, the runtime ratio for a refrigerator under 32˚C ambient temperature is about 50%, and when the temperature drops to 25˚C the runtime ratio is lower, and can reach 38%. Factors such as door opening, defrost strategies and internal loads also contribute to the optimum runtime ratio (Saidur *et al.*, 2002 and Borges *et al*., 2011). The level of influence of each of these factors varies according to each situation and is difficult to capture, which justifies the use of the maximum ratio for this research.

Moreover, in the case of electric geysers, it was found that the respondents tried to estimate the real runtime, which is why the average runtime ratio for this appliance was about 13 hours. However, for the LCC calculation for the proposed energy efficient house, the average runtime was adjusted, from the previous 13 hours per day to 2 hours per day, as suggested by Company A. Company A also indicated that the use of air conditioning and fans, could be adjusted taking into account that on average the summer season lasts for 8 months in Mozambique, households could still use these devices for at least 5 hours a day starting from the middle of September until the middle April. Table 4.14 indicates that when the afore-mentioned adjustments are considered, the total consumption of energy reduces by 16% and 54% for type 2 and type 3 houses, respectively.

Table 4.13: Annual energy consumption of the type 2 and 3 houses including adjustments over the operational time, without considering the use of energy efficient appliances.

Type of appliances	D1*	D2*	D3* (W)	D4* (W)	D5* (h)	D6* (h)	D7* (W/h)	D8* (W/h)
Freezers	1	1	378	300	16	16	6,048	4,800
CFL	11	12	39	32	9	5	2,145	1,920
Incandescent	0	0	0	0	0	0	0	0
Televisions	2	3	196	166	9	9	3,528	4,482
Electric Geysers	1	1	1,653	2,357	13	2	3,306	4,714
Stoves	1	1	1,757	2,945	3	3	5,271	8,835
Kettles	1	1	1,526	1,513	1	1	1,526	1,513
Ironing Machine	1	1	1,162	1,142	1	1	1,162	1,142
DVD	1	1	48	38	3	3	144	114
Air conditioning	1	2	1,703	1,699	8	3	5,109	10,194
Fans	2	2	120	102	6	3	720	612
Microwave	1	1	1,411	1,261	1	1	1,411	1,261
Refrigerator	1	1	414	581	16	16	6,624	9,296
Sound amplifiers	1	1	52	96	4	4	208	384
Radios	1	1	49	67	4	4	196	268
Space heaters	1	1	1,370	2,175	1	0	0	0
Other appliances								
Computers	1	1	513	419	4	4	2,052	1,676
Toasters	1	1	505	723	3	3	1,515	2,169
Total W/h/day							40,965	53,380
Total kWh/year							14,747	19,217

*Note: D1=Number of appliances in a type 2 house, D2=Number of appliances in a type 3 house, D3= Average of the appliances power capacity in a type 2 house, D4=Average of the appliances power capacity in a type 3 house, D5=Average of the time that the appliances remain operational in both types of houses, D6=Suggested time to keep the appliances operational, D7=Total Energy consumed by the appliances in Watt hour – For the type 2 houses , D8=Total Energy consumed by the appliances in Watt hour – For the type 3 houses.

Table 4.15 indicates the LCC of the type 2 and 3 energy efficient houses considering that energy efficient elements are incorporated while developing the house. The initial investment for acquiring the house is surprisingly about 2,134,458.25MT, which is approximately 5% cheaper than the actual cost of buying one of the types 2 surveyed houses. It was also found that the initial investment cost of the type 3 energy efficient designs to be lower than the cost of acquiring similar house in Maputo city, which was around 11% lower compared to those which do not incorporate energy efficient measures (See more details in Appendix I).

Many reasons account for this situation, for example there is the issue of price speculation, which in this case could be explained by the fact that the targeted area is located in the central city of Maputo, where there is a great demand for houses. Nevertheless, the findings clearly indicate potential savings not only with the annual energy consumption but also in the initial investment.Consequently, the LCC for the equivalent type 3 house that incorporates energy efficient measures is 5% lower than that of type 3 house, contrary, the LCC of the type 2 houses is nearly 1.5% higher than that of a type 2 house. .The relative minor savings is due to the fact that there are minor differences in the required amount for the initial investment in both situations.

Table 4.14 : LCC for type 2 and 3 houses that are energy efficient, without considering the use of energy efficient appliances.

Item	Description of cost	Present Value of Type 2 House (MT)	Present Value of Type 3 House (MT)
1	Total Initial Investment (house and appliances)	2,255,624.25	3,394,359.50
2	Total cost for appliances replacement	5,153,761.29	6,252,603.12
3	Operating costs for the first 6 years	266,399.53	336,837.21
4	Operating costs, for the remaining 44 years	771,248.35	974,740.18
5	Maintenance costs	573,683.87	872,801.23
6	Residual Value	(1,399.05)	(2,128.51)
7	Total LCC in MT	9,019,318.24	11,829,212.71

4.3.4. LCC of energy efficient building with energy efficient appliances

Considering that not only energy efficient elements are taken into consideration while building a new house but also are the energy efficient appliances adopted by the households, the LCC of the building reduces significantly. Table 4.15 disregard the use of efficient appliances, Table 4.16 on the other hand includes this analysis. The total energy consumption of the households was adjusted by the suggested factor of 50% improvement over the appliances, further adjustments were made to the time that the appliances remains operational per day and electric heaters and incandescent light were eliminated (See Appendix J for more details). However it should be noted that while electric heaters were considered dispensable, incandescent lights were replaced by CFL, as they are more energy efficient.

Table 4.15: LCC for type 2 and 3 energy efficient houses, considering the use of energy efficient appliances.

Item	Description of cost	E1* (MT)	E2* (MT)
1	Initial Investment (house and appliances)	2,316,207.25	3,467,859,50
2	Total cost for appliances replacement	7,730,641.93	9,378,904.67
3	Operating costs for the first 6 years	139,778.91	168,416.85
4	Operating costs, for the remaining 44 years	385,634.64	487,365.02
5	Maintenance costs	573,683.87	872,801.23
6	Residual Value	(1,399.05)	(2,128.51)
7	Total LCC (MT)	11,144,547.55	14,773,814.08

*Note: E1= Present value for type 2 house considering an improvement of 50% of the appliances power capacity, E2=Present value for type 3 house considering an improvement of 50% of the appliances power capacity.

According to Table 4.16 the LCC of the building considering energy efficient building combined with 50% improvements of the household’s appliances indicates an increase of about 20% and 14% of the building LCC of the proposed type 2 and type 3 energy efficient houses in comparison to each similar typical house. This relative high LCC is the result of additional costs that will be required to acquire the energy efficient appliances, despite the fact of the initial investment of acquiring both energy efficient proposed being relative cheaper than the type 2 and 3 houses, see Appendix L for more details.

Table 4.17 illustrates the sensitivity analysis of the implementation of different energy efficient measures in the type 2 and type 3 houses, as well as on the proposed energy efficient designs. The combination of energy efficiency strategies in the building envelope and use of more energy efficient appliances result in the increase of the LCC of the both types of houses. The table indicates cost reductions of the building energy consumption during its useful life time in the cases where energy efficient measures are considered, ranging with reductions of 56% and 68% for the types 2 and 3 houses, respectively.

Previous studies by Adalberth (1997) and Baccali *et al.*, (2013) indicate that throughout their life time, it is during the operational phase when buildings consumes most of the required energy to provide its tenants with reasonable indoor comfort, accounting for 85 and 72%, respectively.

The study found that, the additional initial investment to build energy efficient houses is about 2 and 8% for type 2 and type 3 houses, respectively. This is comparable to the 9.5% increase in cost from the study of Keoleian *et al.* (2011).

Table 4.16: Resume of the LCC analysis.

Item	Description of cost	Description of the intervention							
		F*1		F2*		F3*		F4*	
		Type 2 house	Type 3 house	Type 2 house	Type 3 house	Type 2 house	Type 3 house	Type 2 house	Type 3 house
1	G1* (MT)	2,364,559	3,752,179	2,425,142	3,825,679	2,255,624	3,394,360	2,316,207	3,476,860
2	G2* (MT)	5,153,761	6,252,603	7,731,602	9,378,905	5,153,761	6,252,603	7,730,642	9,378,905
3	G3* (MT)	309,997	521,462	133,203	168,417	266,400	336,837	139,779	168,417
4	G4* (MT)	897,465	1,509,008	385,635	487,365	771,248	974,740	385,635	487,365
5	G5* (MT)	160,986	351,613	160,986	351,613	573,684	872,801	573,684	872,801
6	G6* (MT)	(1,470)	(2,363)	(1,470)	(2,363)	(1,399)	(2,129)	(1,399)	(2,129)
7	G7*(MT)	8,885,298	12,384,501	10,835,098	14,209,615	9,019,318	11,829,213	11,144,548	14,373,219

*Note: F1= No intervention is made, F2=50% improvements on appliances energy efficiency, F3= Improvement only on the building envelope, F4= Improvements on the energy efficiency of the building envelope and appliances, G1= Initial Investment (house and appliances), G2= Total cost for appliances replacement, G3= Operating costs for the first 6 years, G4= Operating costs, for the remaining 44 years, G5= Maintenance costs, G6= Residual Value, G7=Total LCC.

When energy efficient measures for the building envelope are taken into account without considering the use of energy efficient appliances the LCC of a type 3 house is 5% lower than that of the equivalent type 3 houses, which does not incorporate any energy efficient measure. This means that the economic feasibility of the proposed energy efficient is only attained for the type 3 house using appliances that are considered to be less efficient, however, more affordable in comparison to those that was considered to be more energy efficient.

These findings are comparable to what Keoleian *et al.* (2001) found in their study. The authors concluded that due to the use of 4% discount rate for the possible mortgage that households would require to invest on the energy efficient measures, the savings were offset, with resulting LCC that is closer to that of house which does not incorporate energy efficient measures. In the Mozambican case, the degree in which the potential savings are offset are even higher, due to the relative high discount rate (around 10%) and inflation rates (and average of 2.6%) that increases the actual cost of adopting energy efficient measures. This is worsen by the fact that all appliances are not locally made, rather they are imported, and are relatively expensive in comparison to countries where they are manufactured.

Moreover, in Mozambique, although the total energy consumption decreases, its real savings are usually offset because of the relatively low electricity prices, when compared to other countries. Each kWh of energy costs between 2.89Mt to 3.20Mt/kWh, which is equivalent to aproximatelly 0.09 to 0.1UDS/kWh, while in South Africa for instance, each kWh costs about 1.4ZAR/kWh, equivalent to 0.14USD/kWh (Eskom, 2015).

Chapter 5: Conclusions and Recommendations

The conclusions and recommendations resulting from the study are highlighted in this chapter. The chapter begins by presenting the main conclusions resulting from the survey, highlighting their relation to the objectives of the thesis. The conclusions are based upon the findings presented and discussed in Chapter 3. Finally, the chapter recommends some necessary actions to be taken to enable the use of energy efficient strategies for the building envelope and appliances, and also recommends further work.

5.1. Conclusions

Energy consumption has been increasing worldwide, and has been one of the central points of debate and analysis recently, mainly because of concerns about supply capacities, depletion of the energy resources, and the adverse environmental implications such as climate change. To lessen these negative effects, many countries and organizations have joined forces to design and implement policies to minimize the global pressure on energy resources. One of the strategies has been to promote the adoption of energy efficiency across all sectors especial within the building sector. However, the residential sector is the largest contributor of this share.

Similar to many other low income countries, Mozambique relies mainly on biofuels and waste to meet most of its energy needs, and nearly 71% of the country's total final consumption is used by the residential sector, consequently the country's' CO_2 emissions are relatively negligible. In Mozambique, the residential sector consumes 91% of the electricity generated by the EDM, yet, only 18% of the population is connected to the national grid. Regardless of having access to clean energy carriers, most of the connected houses still rely on traditional energy carriers to meet part of their energy needs, not only in rural areas but also in urban and *peri*-urban areas.

Throughout their life cycle buildings consume a great deal of energy. However, it is on its operating stage when most of this consumption takes place, ranging from 72 – 90%, driven by the need to provide its occupant with an acceptable degree of indoor comfort. Therefore, this research's focus was on this particular phase of the building lifetime. Optimizing building energy consumption can potentially achieve three dividends, namely, improve energy security, contribute to reduce economic costs and avoid social and environmental implications.

To attain these dividends, different schemes have been implemented worldwide with emphasis on energy efficient practices. They range from building energy codes, setting standards and labeling of appliances, promoting financial incentives programs and providing information in voluntary programs. In terms of building codes, the focus has been on strategies that will lessen the building energy burden throughout its useful lifespan, and strategies such as building orientation, insulation, natural ventilation, landscaping, the use of heat absorbing material and window sizing and shading have been widely discussed and proven to be cost effective. In Mozambique, little has been done to promote the adoption of such strategies, and the result is that the most of the existing buildings do not meet these requirements.

The objective of this study was to assess the economic feasibility related to the implementation of energy efficiency measures in the residential building sector of Mozambique. In this regard case study of this research took place in Mozambique, in the Municipal District of *KaMpfumo* in Maputo city. The survey was conducted in 11 neighborhood of the district, and 233 households were subjected to the questionnaire. The aim of the survey was to estimate the households' energy consumption patterns. From the survey it was noted that of the 233 houses, 57% are individually owned, 36% are rented and the remaining 7% are qualified into other categories. It was inferred that most of the houses surveyed are older than 51 years and the majority are type 2 and type 3 houses, which were the house types considered for the proposed energy efficiency design.

Under the current circumstances, around 70 and 73% of the LCC of the houses occurs during the building operational phase, for type 2 and 3 houses, respectively. It was found that all appliances that are currently being used by the households are relatively inefficient and could be improved by 50%, which resulted in significant reduction of the building's energy consumption, accounting for 56% for type 2 houses and about 68% for type 3 houses.

Overall, the use of energy efficient measures increases the building LCC, except for the case when only energy efficient strategies are incorporated in the building envelope and no improvement is made over the appliances power capacity. The answer for the thesis main objective is that, the economic feasibility of the implementation of energy efficient measures in the residential building of Mozambique, is only verified when these measures are implemented on a type 3 building envelope alone, and improvements over appliances power capacity are disregarded.

5.2. Recommendations

a) The government should enforce policies to enhance energy efficiency practices, such as phasing-out incandescent light bulbs, this could be done by providing tax incentives for the market operators to produce and/or import CFL. The same could be done for all electric appliances used by households, as their cost affects the LCC of the buildings. Moreover, similar to other countries that are enhancing the adoption of building codes, the government could empower certain strategies that are cost effective in the short term, and gradually increase its deployment according to local conditions.

b) Architects and building designers companies should play the role of helping investors and end users to better understand about energy efficient strategies, which in some cases do not have an upfront cost, such as building orientation, and the use of cross ventilation strategies that enables the building to rip the benefits of natural ventilation. As mentioned in the thesis, these strategies reduce the building energy consumption.

b) There is a need for massive dissemination of the advantages of energy efficient practices to the building's end users in the Mozambican to increase their awareness about the potential benefits that these measures can accomplish. This dissemination's focus should not only be on the cost effectiveness of these practices, but also the emphasis should be placed on the potential environmental benefits.

c) Further studies should analyze the pay-back period of new buildings, taking into consideration energy efficient strategies during the building conceptual and operating phases, in relation to conventional buildings solutions. This analysis could help building sector stakeholders to better understand the advantages or disadvantages of implementing energy efficiency practices in the Mozambican residential sector.

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Appendices

Appendix A: Survey questionnaire for energy efficiency study

A1: English version of the questionnaire

SURVEY QUESTIONNAIRE FOR ENERGY EFFICIENCY STUDY

This questionnaire aim to evaluate how much does households spend for energy bills, throughout the lifetime of a building. For that, it will access aspects such as sources and cost of energy, appliances that are currently being used, and how much energy do they require for operating among others. With the information provided, suggestions of energy efficient practices that could result in reducing the energy bill could be drawn. Moreover, the suggested improvements may help reduce the increasing pressure towards energy demand within the country. Your responses will be confidential and will be used only for the survey propose.

1. What is the ownership status of this dwelling?
   Owned
   Rented
   Other (specify)

2. What is the dwelling type of building?

Designation	Tick where it is applicable
Conventional house	
Flat/Apartment block	
Hut	
makeshift home	
mixed house	
Basic house	
Part of a commercial building	
Other (specify)	

3. How old is the building?

Designation	Tick where it is applicable
Less than 5 years	
Between 6 and 10 years	

Between 11 and 20 years	
Between 21 and 30 years	
Between 31 and 40 years	
Between 41 and 50 years	
More than 51 years	
Not known	

4. Do you know how much does the house costs currently?
   Yes
   No

5. If yes, can you tell, how much is it in National currency?
   __________________________ *Meticais.*

6. Do you know the annual average costs for the house maintenance?
   Yes
   No
7. If yes, can you tell, how much is it in National currency?
   __________________________ *Meticais.*

8. What is the floor area of this dwelling?
   _______m^2

9. What is the orientation of the house according to the long axis of the building ?
   East-West
   North South
   other

10. How many compartments the household has?

Compartment type	Quantity
Porch	
Bedroom	
Bathroom	
Kitchen	
Corridor	
Living room	
Dining room	
Office	
Other	

11. Energy cost monthly

Months	Electricity (kwh)	LPG (Kg)	Charcoal (kg)	Diesel Oil -generator (Litres)	Coal (kg)	Querosene (litres)	Firewood (Kg)	Other
Cost per unit								
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								

12. Does the household have solar PV system installed and operational
    Yes
    No
13. If yes, what is the installed capacity? To what propose is it being used?

    ____

    ____

14. Which of the following appliances are currently being used by the household?

Designation		Age (years)	Power Capacity (W)	Quantity	Time: h/day	Total	Energy consumption (KWh)
Freezers							
Lighting	Compact Fluorescent						
	Incandescent						
Televisions							
Electric Geysers							
Stoves							
Kettles							

Ironing Machine						
DVD						
Air conditioning						
Fans						
Microwave						
Refrigerator						
Sound amplifiers						
Radios						
Electric space heaters						
Other appliances						
1.						
2.						

15. Do you think that it is important to use energy efficiently?
    Yes
    No
    Other

16. If yes, what measures do you adopt?
    a) ____________________
    b) ____________________
    c) ____________________
    d) None

17. Can you name two energy related issues affecting the world?
a) ____________________
b) ____________________
c) Do not know.

Thank you for answering the questions

A2: Questionnaires' Portuguese version:

QUESTIONÁRIO PARA PESQUISA SOBRE EFICIÊNCIA ENERGÉTICA EM EDIFÍCIOS RESIDENCIAIS

Este questionário tem como objetivo avaliar níveis de consumo de energia pelos agregados familiares, ao longo do tempo de vida útil do edifício. Para isso, ele vai incidir sobre aspectos como fontes e custo da energia, aparelhos que estão sendo usados, e quanta energia estes necessitam para operar entre outros. Com as informações fornecidas, espera-se desenhar *recomendações de práticas energeticamente eficientes que podem resultar na redução da conta de energia dos agregados familiares. Ademais, as melhorias sugeridas podem ajudar a reduzir a crescente procura de energia no país como um todo. Suas respostas são confidenciais e serão utilizadas apenas para a pesquisa em causa.*

1. *Qual é a situação da residência em termos de título de propriedade?*
   a) *Dono*
   b) *Arrendada*
   c) *Outros (especificar)*

2. *Em que categoria a residência se enquadra?*

Designação	*Assinale onde é aplicável*
Casa Convencional	
Flat/Apartamento	
Palhota	
Casa improvisada	
Casa mista	
Casa básica (casa comboio)	
Parte de um edifício comercial	
Outro (Especificar)	

3. *Quantos anos têm o edifício?*

Designação	*Assinale onde é aplicável*
Menos de 5 anos	
Entre 6 a 10 anos	
Entre 11 a 20 anos	
Entre 21 a 30 anos	
Entre 31 a 40 anos	
Entre 41 a 50 anos	
Mais de 51 anos	
Desconhece	

4. *Sabe dizer qual o custo actual da residência no mercado?*
   a) *Sim*
   b) *Não*

5. *Se sim, pode dizer indicar o valor, em moeda nacional?*

   ______________________________ *Meticais*

6. *Sabe dizer qual a média do custo anual para manutenção da residência?*

a) Sim
b) Não

7. *Se sim, pode dizer indicar o valor, em moeda nacional?*
______________________________ *Meticais*

8. *Qual é a área do piso desta habitação?*
____________m^2

9. *Qual é a orientação da casa de acordo com o eixo longo do edifício?*
a) Leste-Oeste
b) Norte Sul
c)Outro

10. *Quantos compartimentos têm a residência?*

Tipo de Compartimento	*Quantidade*
Varanda	
Quarto	
Casa de banho	
Cozinha	
Corredor	
Sala de estar	
Sala de jantar	
Escritório	
Other	

11. *Custo mensal de energia*

Months	*Electricidade (kwh)*	*Gás Doméstico (Kg)*	*Carvão (kg)*	*Gasolina - gerador (Litros)*	*Carvão Mineral (kg)*	*Petróleo (litres)*	*Lenha (Kg)*	*Outros*
Custo por unidade								
Janeiro								
Fevereiro								
Março								
Abril								
Maio								
Junho								
Julho								
Agosto								

Setembro								
Outubro								
Novembro								
Dezembro								

12. *Será que o agregado familiar tem um sistema solar fotovoltaico instalado e operacional*
    a) *Sim*
    b) *Não*

13. *Se sim, qual é a capacidade instalada? Para o que propósito é que está sendo usado?*
    ____
    ____

14. *Qual dos seguintes aparelhos estão sendo usados atualmente pelo agregado familiar?*

Designação		*Idade (anos)*	*Capacidade de Alimentação (W)*	*Quantidade*	*Tempo: hora/dia*	*Total*	*consumo de energia (KWh)*
Geleira							
Lâmpadas	*Fluorescente*						
	Encadescente						
Televisores							
Termo acumulador							
Fogão							
Chaleira eléctrica							
Ferro de engomar							
DVD							
Ar condicionados							
Ventoinhas							
Micro ondas							
Congelador							
Amplificar sonoro							
Radios							
Aquecedores eléctricos							
Outros aparelhos							
1.							
2.							

15. *Você acha que é importante usar a energia de forma eficiente?*
    a) *Sim*
    b) *Não*
    c)*Outro*

16. *Se, sim que medidas tem adoptado?*
    a) ____
    b) ____
    c) ____
    d) *Nenhuma*

17. *Você pode citar duas questões relacionadas com a energia que afetam o mundo*
    a) ____
    b) ____
    c) *Desconhece*

OBRIGADA POR RESPONDER AS QUESTÕES.

Appendix B: Data Summary of the Survey

Table B 1: Compiled answers for questions number 1 and 2 of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang. A	Coop	Total	
Sample Size	38	28	27	24	23	23	22	20	19	16	13	253	
Number of surveyed houses	38	28	27	24	23	3	22	20	19	16	13	233	
%	16%	12%	12%	10%	10%	1%	9%	9%	8%	7%	6%	100%	
Question 1	Ownership status of the house.											Total	%
Owner	30	17	10	18	11	2	16	8	12	9	1	134	58%
Rented	8	11	13	4	12	1	5	12	7	7	3	83	36%
other	-	-	4	2	-	-	1	-	-	-	9	16	7%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%
Question 2	Building type											Total	%
Conventional house type 2	7	2	0	0	0	0	0	0	0	8	0	17	7%
Conventional house type 3	8	3	2	3	2	3	4	0	3	0	1	29	12%
Conventional house type 4	6	0	0	0	0	0	0	0	2	0	0	8	3%
Conventional house type 5	1	0	0	0	0	0	0	0	0	0	0	1	0%
Flat/Apartment block type 1	0	0	1	0	0	0	0	4	0	0	0	5	2%
Flat/Apartment block type 2	4	7	13	4	7	0	6	8	4	3	5	61	26%
Flat/Apartment block type 3	9	16	10	17	9	0	12	8	7	5	7	100	43%
Flat/Apartment block type 4	3	0	0	0	5	0	0	0	3	0	0	11	5%
Part of a commercial building	0	0	1	0	0	0	0	0	0	0	0	1	0%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%

Table B 2: Compiled answers for questions number 3, 4 and 5 of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop	Total	
	Age of the building.											Total	%
Less than 5 years	0	1	1	0	0	0	0	0	0	0	0	2	1%
Between 6 and 10 years	1	0	0	1	0	0	0	0	0	0	0	2	1%
Between 11 and 20 years	0	3	0	1	1	2	0	0	0	0	3	10	4%
Between 21 and 30 years	1	0	1	0	1	0	1	0	0	0	6	10	4%
Between 31 and 40 years	2	0	0	2	6	0	1	0	1	1	1	14	6%
Between 41 and 50 years	9	0	1	1	3	0	3	0	2	5	2	26	11%
More than 51 years	18	16	14	6	1	0	13	14	16	8	0	106	45%
Not known	7	8	10	13	11	1	4	6	0	2	1	63	27%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%
	Cost of the houses.											Total	%
Yes	26	12	4	6	5	2	9	3	16	12	3	98	42%
No	12	16	23	18	18	1	13	17	3	4	10	135	58%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%
	Average acquisition cost in National currency.											Total	Average
Conventional house type 2	1,312,500	2,500,000	-	-		-	-	-	-	542,857	-	4,355,357	1,451,786
Conventional house type 3	2,014,286	3,500,000	-	-		6,500,000	7,000,000	-	3,500,000	-	-	22,514,286	4,502,857
Conventional house type 4	2,760,000	-	-	-		-	-	-	5,750,000	-	-	8,510,000	4,255,000
Conventional house type 5	-	-	-	-		-	-	-	-	-	-	-	-
Flat/Apartment block type 1	-	-	-	-		-	-	1,500,000	-	-	-	1,500,000	1,500,000
Flat/Apartment block type 2	2,800,000	5,500,000	2,750,000	3,600,000	1,500,000	-	5,666,667	1,500,000	4,333,333	700,000	2,000,000	30,350,000	3,035,000
Flat/Apartment block type 3	2,000,000	1,625,000	6,000,000	1,850,000	1,750,000	-	4,625,000	1,700,000	4,000,000	775,000	2,750,000	27,075,000	2,707,500
Flat/Apartment block type 4	2,500,000	-	-	-		-	-	-	5,000,000	-	-	7,500,000	3,750,000
Part of a commercial building	-	-	2,000,000	-		-	-	-	-	-	-	2,000,000	2,000,000

Table B 3: Compiled answers for questions number 6 and 7 of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Annual average cost for the house’s maintenance.											Total	%
Yes	26	13	4	3	5	3	8	3	13	13	9	100	43%
No	12	15	23	21	18	0	14	17	6	3	4	133	57%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%
	Average cost in National currency.											Total	Average
Conventional house type 2	23,000	5,000	-	-	-	-	-	-	-	4,143	-	32,143	10,714
Conventional house type 3	27,333	15,000	65,000	-	-	34,000	20,000	-	20,000	-	20,000	201,333	28,762
Conventional house type 4	55,000	-	-	-	-	-	-	-	22,500	-	-	77,500	38,750
Conventional house type 5	-	-	-	-	-	-	-	-	-	-	-	-	-
Flat/Apartment block type 1	-	-	-	-	-	-	-	20,000	-	-	-	20,000	20,000
Flat/Apartment block type 2	2,000	12,500	30,000	20,000	-	-	20,000	5,000	15,000	7,500	7,200	119,200	13,244
Flat/Apartment block type 3	19,714	12,125	40,000	37,500	35,250	-	33,400	20,000	13,000	10,250	14,429	235,668	23,567
Flat/Apartment block type 4	56,667	-	-	-	200,000	-	-	-	12,333	-	-	269,000	89,667
Part of a commercial building	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B 4: Compiled answers for questions number 9 and 11 of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Somershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Building orientation											Total	%
East-West	10	13	13	15	16	2	10	10	9	7	3	108	46%
North – South	25	15	14	9	7	1	12	10	9	9	4	115	49%
Other	3	0	0	0	0	0	0	0	1	0	6	10	4%
Total	38	28	27	24	23	3	22	20	19	16	13	233	100%
	Energy Sources											Total	
Electricity	38	28	27	24	23	3	22	20	19	16	13	233	100%
LPG	38	26	23	21	19	3	20	17	18	16	12	213	91%
Charcoal	37	25	6	0	3	3	8	0	11	16	13	122	52%
Diesel oil-Generator	0	0	0	0	0	0	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Querosene	0	0	0	0	0	0	0	0	0	0	0	0	0
Firewood	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
	Percentage												
Electricity	100%	100	100%	100%	100%	100%	100%	100%	100%	100%	100%		
LPG	100%	93%	85%	88%	83%	100%	91%	85%	95%	100%	92%		
Charcoal	97%	89%	22%	0%	13%	100%	36%	0%	58%	100%	100%		
Diesel oil-Generator	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Coal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Querosene	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Firewood	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		

Table B 5: Compiled answers for question number 14a of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Age of the appliances											Total	Average
Freezers	4	7	6	5	5	3	9	5	13	3	4	65	6
CFL	1	3	1	1	1	1	2	1	4	1	1	15	1
Incandescent	0	2	1	1	1	1	2	1	2	1	0	11	1
Televisions	4	5	4	5	4	2	8	4	7	2	2	49	4
Electric Geysers	1	4	3	5	4	4	8	5	2	1	8	44	4
Stoves	3	4	3	4	4	3	7	5	6	3	1	44	4
Kettles	2	4	2	1	2	1	4	2	7	1	1	28	3
Ironing Machine	2	3	2	4	3	2	5	3	6	1	3	34	3
DVD	4	4	3	3	4	3	5	2	7	1	2	39	4
Air conditioning	2	2	3	1	4	3	8	4	10	3	3	43	4
Fans	2	3	3	2	2	5	7	4	12	1	2	42	4
Microwave	2	3	3	3	2	2	5	3	8	2	2	34	3
Refrigerator	5	6	6	9	3	4	11	7	12	4	5	71	6
Sound amplifiers	3	4	4	2	6	3	4	4	14	2	2	48	4
Radios	3	6	5	9	2	6	9	5	4	1	3	53	5
Electric space heaters	1	1	1	2	1	2	8	1	2	0	5	23	2
Other						-	-	-	-	-	-	-	-
Computers	3	4	3	2	3	2	5	6	9	2	2	40	4
Toasters	1	4	2	2	2	2	6	3	10	3	1	36	3

Table B 6: Compiled answers for question number 14b of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Time that the appliances remain turned on per day.											Total	Average
Freezers	16	16	16	16	16	16	16	16	16	16	16	176	16
CFL	9	8	10	13	8	9	8	10	6	12	9	102	9
Incandescent	9	8	5	10	5	6	7	8	5	12	5	81	7
Televisions	10	6	10	16	9	14	7	11	3	8	8	102	9
Electric Geysers	4	1	20	18	11	24	13	27	1	7	19	144	13
Stoves	4	2	3	2	2	7	3	3	1	4	1	32	3
Kettles	1	1	1	1	1	0	1	1	1	0	0	8	1
Ironing Machine	2	1	1	1	2	2	1	1	1	3	1	15	1
DVD	5	3	3	3	3	3	2	4	3	3	1	34	3
Air conditioning	10	3	9	10	7	11	7	8	4	16	4	88	8
Fans	8	4	7	3	10	0	4	8	3	15	2	64	6
Microwave	1	1	0	1	0	0	1	1	1	2	0	9	1
Refrigerator	16	16	16	24	16	16	16	16	16	16	16	176	16
Sound amplifiers	4	3	4	1	7	3	2	6	6	3	0	39	4
Radios	4	4	3	5	7	4	4	4	1	5	0	40	4
Electric space heaters	1	0	2	1	5	1	3	0	0	1	0	14	1
Other appliances					0	0	0	0	0	0	0	0	0
Computers	5	5	7	1	7	3	3	9	3	4	1	47	4
Toasters	1	1	2	2	2	5	2	10	2	4	0	30	3

Table B 7: Compiled answers for question number 14c (i) of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Total Energy consumption of the appliances for type 2 apartment block.											Total	Average
Freezers	5,600	6,560	17,009	3,360	5,866	-	3,744	3,040	3,840	9,226	2,048	60,295	6,029
CFL	3,625	707	4,372	9,120	1,128	-	2,737	1,420	848	4,540	2,419	30,916	3,092
Incad.	2,440	1,665	2,804	1,800	3,276	-	4,880	2,086	2,700	3,800	1,710	27,161	2,716
TV	1,185	1,221	3,111	2,610	2,350	-	2,652	2,741	863	6,440	1,898	25,071	2,507
Geyser	12,000	1,500	76,357	12,000	28,750	-	21,350	57,000	-	-	30,120	239,077	29,885
Stoves	10,900	4,375	7,786	8,000	2,667	-	7,600	9,900	-	9,333	-	60,561	7,570
Kettles	419	835	2,005	1,343	963	-	974	2,435	1,300	667	679	11,619	1,162
Iron.	3,650	830	1,235	981	1,038	-	540	1,786	788	3,200	1,460	15,508	1,551
DVD	175	50	519	90	71	-	99	194	97	85	8	1,387	139
AC	-	-	44,000	18,800	17,500	-	23,100	10,400	10,400	40,300	3,450	167,950	20,994
Fans	2,060	452	1,200	965	1,950	-	380	1,053	387	1,747	5	10,198	1,020
Microwave	2,200	1,688	672	1,500	419	-	863	650	1,075	2,067	129	11,262	1,126
Refrig.	5,333	3,787	36,016	2,240	5,680	-	3,960	2,480	3,040	5,680	2,880	71,096	7,110
Sound amplif.	111	183	2,295	-	90	-	137	2,550	130	175	2	5,673	630
Radios	106	381	108	407	1,800	-	130	200	80	-	7	3,219	358
heaters	-	750	-	2,000	-	-	7,750	13	-	4,200	-	14,713	2,943
Other													
Comp.	3,300	974	2,633	-	1,930	-	1,337	813	467	2,200	121	13,774	1,530
Toast.	2,700	250	2,965	-	253	-	865	6,000	250	5,000	85	18,368	2,041
Total w/h/day	40,478.00	17,213.00	114,562.38	41,911.25	44,457.62	-	54,465.94	53,421.90	13,026.25	75,113.33	47,019.97	501,669.66	50,166.97
Total Kwh/day	40,478	17,213	114,562	41,911	44,458	-	54,466	53,422	13,026	75,113	47,020	501,670	50,167
Cost per kWh	40	17	115	42	44	-	54	53	13	75	28	483	48
	3	3	3	3	3	-	3	3	3	3	3	30	3
Daily cost													
Monthly cost	130	55	339	127	133	-	163	154	38	217	85	1,441	144
Total annual cost	3,886	1,652	10,176	3,803	3,990	-	4,885	4,632	1,129	6,512	2,559	43,225	4,322
kWh/year	6,631	19,829	122,114	45,635	47,878	-	58,621	55,580	13,553	78,148	30,710	518,698	51,870

Table B 8: Compiled answers for question number 14c (ii) of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Total Energy consumption of the appliances for type 2 apartment block											Total	Average
Freezers	7,093	7,027	7,456	3,120	3,952	-	2,942	2,936	2,800	11,936	2,120	51,383	5,138
CFL	2,720	580	4,654	6,090	1,257	-	1,105	2,449	1,171	5,112	2,624	27,762	2,776
Incan	3,709	1,479	3,408	3,641	6,768	-	2,133	1,800	1,100	4,620	1,861	30,519	3,052
TV	6,300	1,562	4,138	13,884	5,599	-	1,804	5,912	1,223	8,914	2,199	51,535	5,154
Geysers	17,338	1,044	46,933	44,160	32,700	-	28,240	53,600	3,500	34,500	63,000	325,015	32,502
Stoves	14,996	3,171	31,300	3,508	6,690	-	6,400	8,833	7,250	11,920	5,600	99,668	9,967
Kettle	486	1,023	863	990	984	-	908	1,704	1,280	745	625	9,607	961
Iron.	4,038	506	1,985	962	1,960	-	934	2,017	893	9,520	1,591	24,407	2,441
DVD	239	116	149	96	2,250	-	78	127	158	129	81	3,423	342
AC.	77,440	3,800	82,963	58,608	42,544	-	25,484	29,095	6,200	57,450	1,350	384,935	38,493
Fans	1,643	589	3,260	223	500	-	840	920	663	4,090	231	12,959	1,296
Microwave	1,867	1,565	818	757	296	-	647	1,084	1,200	3,440	952	12,625	1,263
Refrig	10,560	5,017	8,360	3,947	6,333	-	4,889	3,337	4,200	6,432	1,947	55,022	5,502
Sound amplif	202	143	849	364	800	-	165	828	840	185	51	4,427	443
Radio	162	552	205	550	54	-	270	240	150	720	87	2,990	299
heater	-	-	8,000	4,000	30,000	-	6,000	-	-	-	600	48,600	9,720
Other	-	-	-		-		-	-	-	-	-	-	-
Comp.	3,328	817	4,483	536	5,428	-	3,649	2,975	527	3,475	64	25,282	2,528
Toast.	2,525	120	954	4,220	2,832	-	1,278	888	513	3,100	139	16,567	1,657
Total W/h/day	106,384	19,250	136,861	102,895	93,772	-	64,311	60,111	15,509	121,293	51,453	771,839	77,184
kWh/day	106	19	137	103	94	-	64	60	16	121	51	772	77
Cost/kWh	3	3	3	3	3	-	3	3	3	3	3	29	3
daily cost	333	60	397	303	271	-	186	174	45	351	149	2,268	227
Monthly cost	9,992	1,803	11,925	9,091	8,130	-	5,576	5,212	1,345	10,516	4,461	68,050	6,805

Annual cost	119,908	21,635	143,100	109,091	97,560	-	66,909	62,539	16,136	126,193	53,532	816,604	81,660
kWh per year	38,298	6,930	49,270	37,042	33,758	-	23,152	21,640	5,583	43,665	18,523	277,862	27,786

Table B 9: Compiled answers for question number 14c (iii) of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Total Energy consumption of the appliances for type 2 conventional houses.											Total	Average
Freezers	8,411	4,000	-	-	-	-	-	-	-	8,766	-	21,177	7,059
CFL	2,880	412	-	-	-	-	-	-	-	6,188	-	9,480	3,160
Incandescent	2,800	880	-	-	-	-	-	-	-	4,370	-	8,050	2,683
Televisions	3,071	1,487	-	-	-	-	-	-	-	6,247	-	10,805	3,602
Electric Geysers	8,433	-	-	-	-	-	-	-	-	9,150	-	17,583	8,792
Stoves	8,811	3,125	-	-	-	-	-	-	-	9,189	-	21,126	7,042
Kettles	464	1,933	-	-	-	-	-	-	-	763	-	3,161	1,054
Ironing Machine	2,370	825	-	-	-	-	-	-	-	6,466	-	9,661	3,220
DVD	228	75	-	-	-	-	-	-	-	100	-	403	134
Air condit.	24,940	-	-	-	-	-	-	-	-	25,880	-	50,820	25,410
Fans	1,829	720	-	-	-	-	-	-	-	4,995	-	7,544	2,515
Microwave	900	-	-	-	-	-	-	-	-	3,650	-	4,550	2,275
Refrigerator	6,331	3,467	-	-	-	-	-	-	-	9,280	-	19,078	6,359
Sound amplifiers	151	90	-	-	-	-	-	-	-	132	-	373	124
Radios	170	720	-	-	-	-	-	-	-	80	-	970	323
Electric space heaters	-	500	-	-	-	-	-	-	-	-	-	500	500
Other appliances										-		-	-
Computers	1,640	1,375	-	-	-	-	-	-	-	3,677	-	6,692	2,231
Toasters	-	-	-	-	-	-	-	-	-	2,267	-	2,267	2,267
Total W/h/day	49,602	14,519	-	-	-	-	-	-	-	78,104	-	142,225	47,408
Total kWh/day	49.60	14.52	-	-	-	-	-	-	-	78.10	-	142.23	47.41
Cost per kWh	3.11	3.20	-	-	-	-	-	-	-	2.89	-	9.20	3.07
Total daily cost	156.15	46.46	-	-	-	-	-	-	-	225.72	-	428.33	142.78
Monthly cost	4,684	1,394	-	-	-	-	-	-	-	6,772	-	12,850	4,283
Total annual cost	56,214	16,726	-	-	-	-	-	-	-	81,259	-	154,199	51,400
kWh per year	17,857	5,227	-	-	-	-	-	-	-	28,117	-	51,201	17,067

Table B 10: Compiled answers for question number 14d (vi) of the questionnaire.

Neighborhood	Malhang. B	Alto Mae B	Central B	Central A	P. Cimto. A	Sommershield	P.Cimto. B	Central C	Alto Mae A	Malhang.A	Coop		
	Total Energy consumption of the appliances for type 3 conventional houses.											Total	Average
Freezers	11,180	2,720	13,120	3,120	3,360	8,160	3,280	-	2,827	-	2,080	49,847	5,539
CFL	3,338	1,530	3,900	3,813	808	1,640	4,797	-	1,266	-	2,024	23,116	2,568
Incan.	5,751	3,600	2,400	1,440	-	4,730	4,200	-	7,200	-	-	29,321	4,189
TV	5,018	2,100	1,624	3,360	180	16,900	8,520	-	1,633	-	2,400	41,735	4,637
Geysers	-	1,550	10,000	60,000	-	153,600	42,000	-	-	-	16,000	283,150	47,192
Stoves	18,475	1,720	6,000	3,000	-	18,000	5,075	-	6,000	-	-	58,270	8,324
Kettle	1,119	1,500	4,540	550	333	725	4,378	-	1,900	-	400	15,445	1,716
Iron.	1,499	650	3,639	428	2,500	5,467	1,163	-	458	-	1,100	16,904	1,878
DVD	306	-	130	53	36	420	75	-	150	-	-	1,170	167
AC	21,250	10,800	-	-	24,000	133,400	51,600	-	6,400	-	10,800	258,250	36,893
Fans	3,055	-	1,740	175	180	-	700	-	617	-	660	7,127	1,018
Micro wave	3,250	3,125	-	517	240	1,033	694	-	1,000	-	250	10,109	1,264
Refrig	10,400	2,640	51,840	2,080	-	8,853	4,320	-	2,965	-	3,040	86,139	10,767
Sound amplif	268	-	1,425	45	144	247	135	-	100	-	-	2,364	338
Radio	192	165	630	60	168	325	230	-	-	-	-	1,770	253
Heater	500	-	-	-	-	1,000	4,000	-	750	-	-	6,250	1,563
Other	-	-	-	-	-	-	-		-		-	-	-
Comp.	2,638	1,540	4,375	150	300	3,480	633	-	375	-	-	13,491	1,686
Toast.	250	-	2,200	500	375	1,800	396	-	1,080	-	-	6,601	943
Total W/h/day	75,728	32,865	93,703	37,790	19,903	356,645	116,463	-	20,998	-	38,754	792,849	88,094
Total kWh/day	76	33	94	38	20	357	116	-	21	-	39	793	88
Cost per kWh	3	3	3	3	3	3	3	-	3	-	3	26	3
Total daily cost	242	95	271	109	58	1,031	337	-	61	-	112	2,315	257
Monthly cost	7,270	2,849	8,124	3,276	1,726	30,921	10,097	-	1,820	-	3,360	69,444	7,716
Total annual cost	87,239	34,193	97,489	39,317	20,707	371,053	121,168	-	21,846	-	40,320	833,331	92,592
kWh per year	27,262	11,831	33,733	13,604	7,165	128,392	41,927	-	7,559	-	13,951	285,425	31,714

Appendix C: Interview questionnaire

Interview with Civil Construction Companies and Architects

This interview aims to collect data from the civil construction and building designers companies in Mozambique in order to assess information on the characteristics of existing buildings in Mozambique, particularly in Maputo. This information aim to access current practices to increase the deployment of energy efficient buildings and the demand level for building that are energy efficient .

1. Comany name (Optional)

   ____

2. Position/ or which activity plays?

   ____
   ____

3. The company have a policy on promoting energy efficiency in buildings (Residential and / or Institutional) ?

   ____
   ____

4. If so, what policies or practices have been adopting?

   ____
   ____
   ____
   ____
   ____
   ____

5. Do your customers tend look for options of residential buildings that are energy efficient?

   ____

6. If so, what solutions they tend to look for, or suggestions that your company has recommended, and what advantages such solutions provide to them?

   ____
   ____
   ____

7. In your view , what reasons motivate or discourage potential customers to opt for such solutions?

____
____
____

8. What suggestions would you popularize to promote the construction of residential buildings that are energy efficient?

____
____
____

9. Do you think that, in our economic reality there are practical conditions for such massification ?

____

10. If so , what factors would compete for this?

____
____
____
____

Thank you for your answers

Appendix D: LCC calculation of the type 2 and 3 houses

Table D 1: Estimation cost for acquiring the appliances.

Type of appliances	H1*	H2*	H3*	Total cost	H4*	H5*	H6*	Total cost
Freezers	378	1	30,000.00	30,000.00	300	1	35,000.00	35,000.00
CFL	39	11	106.00	1,166.00	32	12	150.00	1,800.00
Incandes.	0	0	-	-	0	0	-	-
TV	196	2	5,000.00	10,000.00	166	3	7,000.00	21,000.00
Geysers	1653	1	7,000.00	7,000.00	2357	1	5,000.00	5,000.00
Stoves	1757	1	10,000.00	10,000.00	2945	1	8,000.00	8,000.00
Kettles	1526	1	1,500.00	1,500.00	1513	1	1,500.00	1,500.00
Ironing	1162	1	1,500.00	1,500.00	1142	1	1,500.00	1,500.00
DVD	48	1	2,000.00	2,000.00	38	1	2,500.00	2,500.00
AC	1703	1	10,000.00	10,000.00	1699	2	10,000.00	20,000.00
Fans	120	2	1,000.00	2,000.00	102	2	1,500.00	3,000.00
Microwav	1411	1	5,000.00	5,000.00	1261	1	5,000.00	5,000.00
Refriger.	414	1	7,000.00	7,000.00	581	1	7,000.00	7,000.00
Sound amplifiers	52	1	6,000.00	6,000.00	96	1	5,000.00	5,000.00
Radios	49	1	1,000.00	1,000.00	67	1	700.00	700.00
Heaters	1370	1	10,000.00	10,000.00	2175	1	10,000.00	10,000.00
Other	-			-	-			-
Computer	513	1	15,000.00	15,000.00	419	1	18,000.00	18,000.00
Toaster	505	1	2,000.00	2,000.00	723	1	2,000.00	2,000.00
Total cost				121,166.00				147,000.00

*Note: H1= power capacity (type 2 house), H2= type 2 house (appliances quantity), H3= estimated cost, H4= power capacity (type 3 house), H5= type 3 house (appliances quantity), H6= estimated costs.

a) Data Summary

Table D 2: LCC of type 2 houses.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house Acqusition	2,243,392.86	equal to the initial investment	2,243,392.86
2	Initial Investment for Appliances	121,166.00	equal to the initial investment	121,166.00
3	Total Initial Investment	2,364,558.86	-	2,364,558.86
4	Apliances Replacement 1(constant escalation rate of 2.6%)	121,166.00	6.96	842,723.33
5	Apliances Replacement 2 (constant escalation rate of 2.6%)	121,166.00	10.42	1,262,706.39
6	Appliances Replacement 3(constant escalation rate of 2.6%)	121,166.00	12.15	1,472,010.87
7	Appliances Replacement 4(constant escalation rate of 2.6%)	121,166.00	13.01	1,576,320.71
8	Annual Electricity bill: 17,160.39kWh at 3.03MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	51,995.98	5.96	309,996.59
9	Annual Electricity bill: 17,160.39kWh at 5.31*MT/kWh (constant price during the remaining 44 years)	91,121.67	9.85	897,465.42
10	Maintenance cost (constant escalation rate of 2.6%)	11,979.37	13.44	160,986.32
11	Residual Value	(172,617.81)	0.01	(1,470.45)
12	Total LCC (MT)			8,885,298.02

Table D 3: LCC of type 3 houses.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house Acquisition	3,605,178.57	equal to the initial investment	3,605,178.57
2	Initial Investment for Appliances	147,000.00	equal to the initial investment	147,000.00
3	Total Initial Investment	3,752,178.57	-	3,752,178.57
4	Appliances Replacement 1(constant escalation rate of 2.6%)	147,000.00	6.96	1,022,401.74
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	147,000.00	10.42	1,531,930.07
6	Appliances Replacement 3(constant escalation rate of 2.6%)	147,000.00	12.15	1,785,860.70
7	Appliances Replacement 4(constant escalation rate of 2.6%)	147,000.00	13.01	1,912,410.61
9	Annual Electricity bill: 29,750.08kWh at 2.94MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	87,465.24	5.96	521,461.93
10	Annual Electricity bill: 29,750.08kWh at 5.15MT/kWh (constant price during the remaining 44 years)	153,212.91	9.85	1,509,007.56
11	Maintenance cost (constant escalation rate of 2.6%)	26,164.35	13.44	351,613.01
12	Residual Value	(277,400.38)	0.01	(2,363.05)
13	Total LCC (MT)			12,384,501.13

b) Justification of input data to the LCC model

i) Lifetime

In this study, the life time period was taken to be 50 years, which is the same as that used by many other researchers, such as Adalberth (1997), Ramesh *et al*. (2010) and Utama and Gheewala (2008) while calculating LCC of buildings from the energy efficiency point of view.

ii) Initial Investment

The initial investment costs were those incurred in acquiring the house. For the energy efficient design the initial investment was of 2,134,458.25 MT for a type 2 house and of 3,247,359.50MT, taking into account elements such as, but not limited to insulation, double clear glazing. For more details see Appendices 5 and 6.

iii) Operating costs

The operating costs in this thesis are the energy related costs that the household spends during the building lifespan. Despite the fact that, these household energy costs include electricity, LPG and charcoal, for the purpose of this analysis only electricity costs wasconsidered, since they represent their most significant energy cost. The same assumption was considered to estimate the operating costs for the energy efficient designs, for that the research considered the appliances power capacity that company C suggested to be energy efficient (see table4.12). Moreover, this data was combined with what company A?, indicated to be satisfactory in terms of indoor thermal comfort when the suggested estrategies to improve the building energy efficieny are taken into account. It is worth to note that, as stated by company A?, the requirements for air condidioning and heaters for indoor thermal comfort reduces dramatically. Meaning that its usage may be reduced to only few periods of the year.

iv) Maintenance costs

The maintenance cost is the annual cost of maintaining the building during its useful time, in order to preserve its functionalities. The assumption is that these costs vary throughout the life time of the building, in a constant escalating rate. In the case of energy efficient designs this research used an annual cost of 2% of the initial investment, based on what company D, estimated as maintenance costs for the houses in reference.

v) Discount rate

From the finance point of view, there are two different types of finance costs that a particular household could consider while evaluating the benefits of certain financial decision. The first discount rate is that, which banks charge their costumers when borrowing money from them. Additionally, investors could also make the decision based on the opportunity cost of buying a house in detriment of saving the money in financial institutions and earn principal interest (Lutz *et al.,* 2006). In this case it represents the opportunity cost, which should yield at least the equivalent interest rate of the profitability of current financial applications with little risk. In this view, this study considered the opportunity cost based on the average tax that commercial banks from Mozambique were paying for their customers who were interested in saving their financial resources, which is of around 10%.

vi) Escalation Rate

While evaluating future cost, it is important to know that there are many uncertainities that may happen in the future, so, in order to lessen its impact on the results, a correctional factor was considered. In the case of operating costs, they are usually affected by the government decisions, since up until now it is the goverment who regulates the electricity sector. So, in order to approximate this cost to the reality, this studyusedthe energy price escalation price suggested by a study conducted by EDM (2012b), which indicates a constant escalation rate of 9.8% from 2015 until 2020 (6 years), and from there on the prices will stabilise.. However, it should be noted that this price aggravation is yet to approved by the parliament. On the other hand, maintenance costs should also be updated year to year, so the maintenance costs escalation rate was based on the inflation rate of 2.6%. This corresponds to the average of the country's inflation rate during 2014. The study considered inflation rate because it affects the prices of goods and services that are part of the costs of the household maintenance expenditures.

vii) Residual Value

The residual value constitutes the market value of the building after its expected useful life. To calculate the residual value of the buildings under analysis, the amortization method at constant rates was applied, with a rate of 5%during the lifetime of the building. This rate was based on what civil engineers indicated to be the annual average tax of the buildings degradation.

Appendix E: Cost estimation for the energy efficient house - type 2

Table E 1: Cost estimation for type 2 energy efficient house.

Item	Designation of the work	Total cost
1	Preliminary work	239,399.46
2	Earthmoving	173,144.70
3	Concrete form	120,031.33
4	Steel	73,416.18
5	Masonry	100,248.50
6	Coating masonry	212,627.55
7	Finishes on floors	69,124.00
8	Carpentry and Aluminum	205,571.43
9	Formwork	37,530.75
10	Cover and structure	80,667.33
11	Painting	116,851.80
12	hydraulics	75,285.00
13	electrical installation	20,715.00
14	Partial total	1,524,613.03
15	Labors (40%)	609,845.21
16	General total	2,134,458.24

Appendix F: Cost estimation for the energy efficient house - type 3

Table F 2: Cost estimation for the type 3 energy efficient house.

Item	Designation of the work	Total cost
1	Preliminary work	253,894.58
2	Earthmoving	219,669.75
3	Concrete form	208,167.06
4	Steel	118,162.66
5	Masonry	240,733.65
6	Coating masonry	255,656.50
7	Finishes on floors	154,725.00
8	Carpentry and Aluminum	241,618.29
9	Formwork	151,387.95
10	Cover and structure	133,667.13
11	Painting	233,954.94
12	hydraulics	78,285.00
13	electrical installation	29,620.00
14	Partial total	2,319,542.50
15	Labors (40%)	927,817.00
16	General total	3,247,359.50

Appendix G: LCC calculation for type 2 and 3 houses – Considering 50% improvements over appliances power capacity

Table G 3: LCC of type 2 house, considering 50% improvements over appliances power capacity.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house Acquisition	2,243,392.86	equal to the initial investment	2,243,392.86
2	Initial Investment for Appliances	181,749.00	equal to the initial investment	181,749.00
3	Total Initial Investment	2,425,141.86	-	2,425,141.86
4	Appliances Replacement 1(constant escalation rate of 2.6%)	181,749.00	6.96	1,264,973.04
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	181,749.00	10.42	1,893,824.58
6	Appliances Replacement 3(constant escalation rate of 2.6%)	181,749.00	12.15	2,208,250.35
7	Appliances Replacement 4(constant escalation rate of 2.6%)	181,749.00	13.01	2,364,554.49
8	Annual Electricity bill: 7,373.70kWh at 3.03MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	22,342.31	5.96	133,203.38
9	Annual Electricity bill: 7,373.70kWh at 5.31*MT/kWh (constant price during the remaining 44 years)	39,154.35	9.85	385,634.64
10	Maintenance cost (constant escalation rate of 2.6%)	11,979.37	13.44	160,986.32
11	Residual Value	(172,617.81)	0.01	(1,470.45)
12	Total LCC (MT)			10,835,098.19

Table G 4: LCC of a type 3 – Considering 50% improvements over appliances power capacity.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house acquisition	3,605,178.57	equal to the initial investment	3,605,178.57
2	Initial Investment for Appliances	220,500.00	equal to the initial investment	220,500.00
3	Total Initial Investment	3,825,678.57	-	3,825,678.57
4	Appliances Replacement 1(constant escalation rate of 2.6%)	220,500.00	6.96	1,533,602.61
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	220,500.00	10.42	2,297,895.10
6	Appliances Replacement 3(constant escalation rate of 2.6%)	220,500.00	12.15	2,678,791.05
7	Appliances Replacement 4(constant escalation rate of 2.6%)	220,500.00	13.01	2,868,615.92
8	Annual Electricity bill: 9,608.40kWh at 2.94MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	28,248.70	5.96	168,416.85
9	Annual Electricity bill: 9,608.40kWh at 5.15MT/kWh (constant price during the remaining 44 years)	49,483.26	9.85	487,365.02
10	Maintenance cost (constant escalation rate of 2.6%)	26,164.35	13.44	351,613.01
11	Residual Value	(277,400.38)	0.01	(2,363.05)
12	Total LCC (MT)			14,209,615.07

Appendix H: Blue print of energy efficient houses

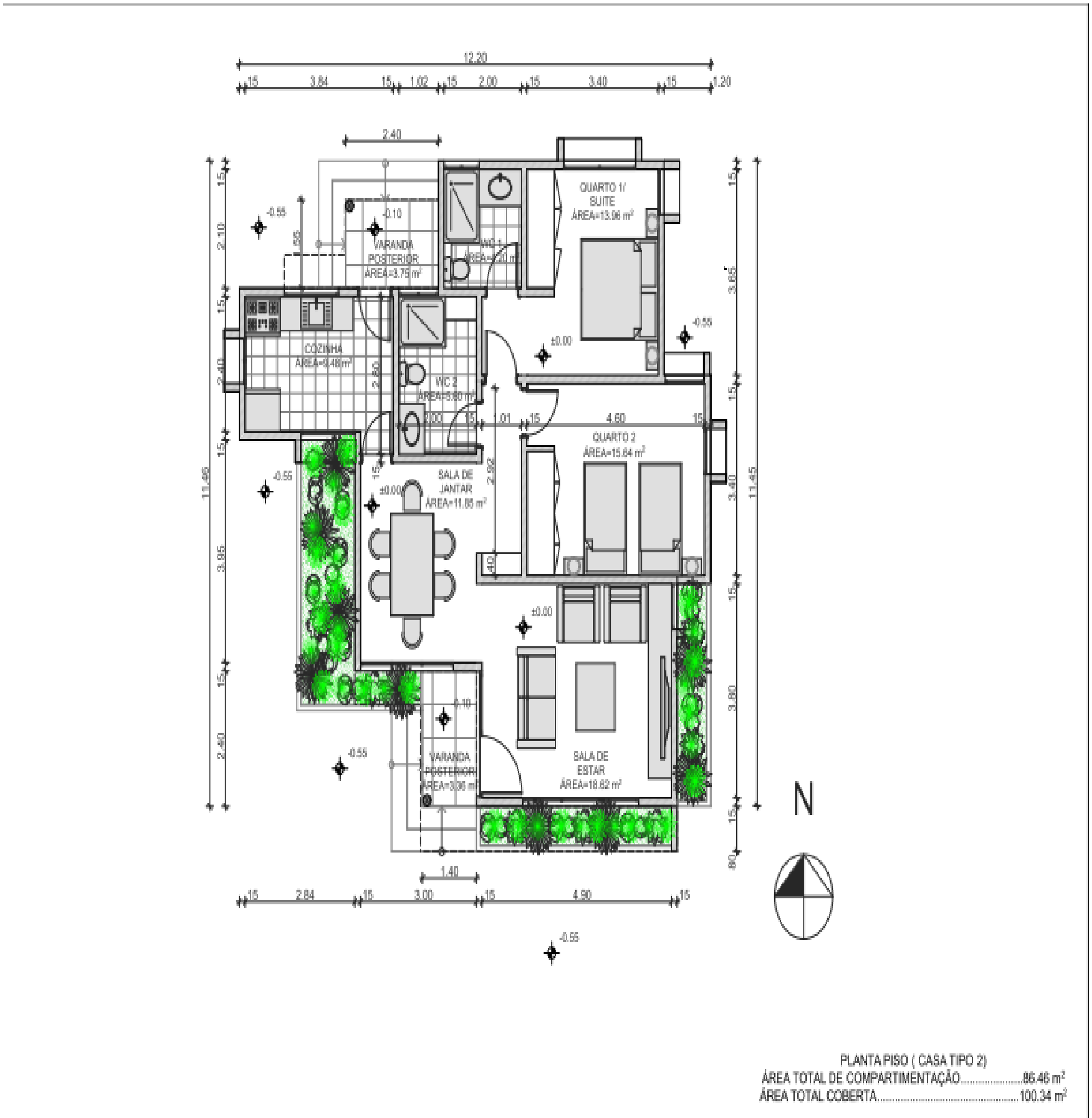

Figure H 1: Blue print of a type 2 energy efficient house.

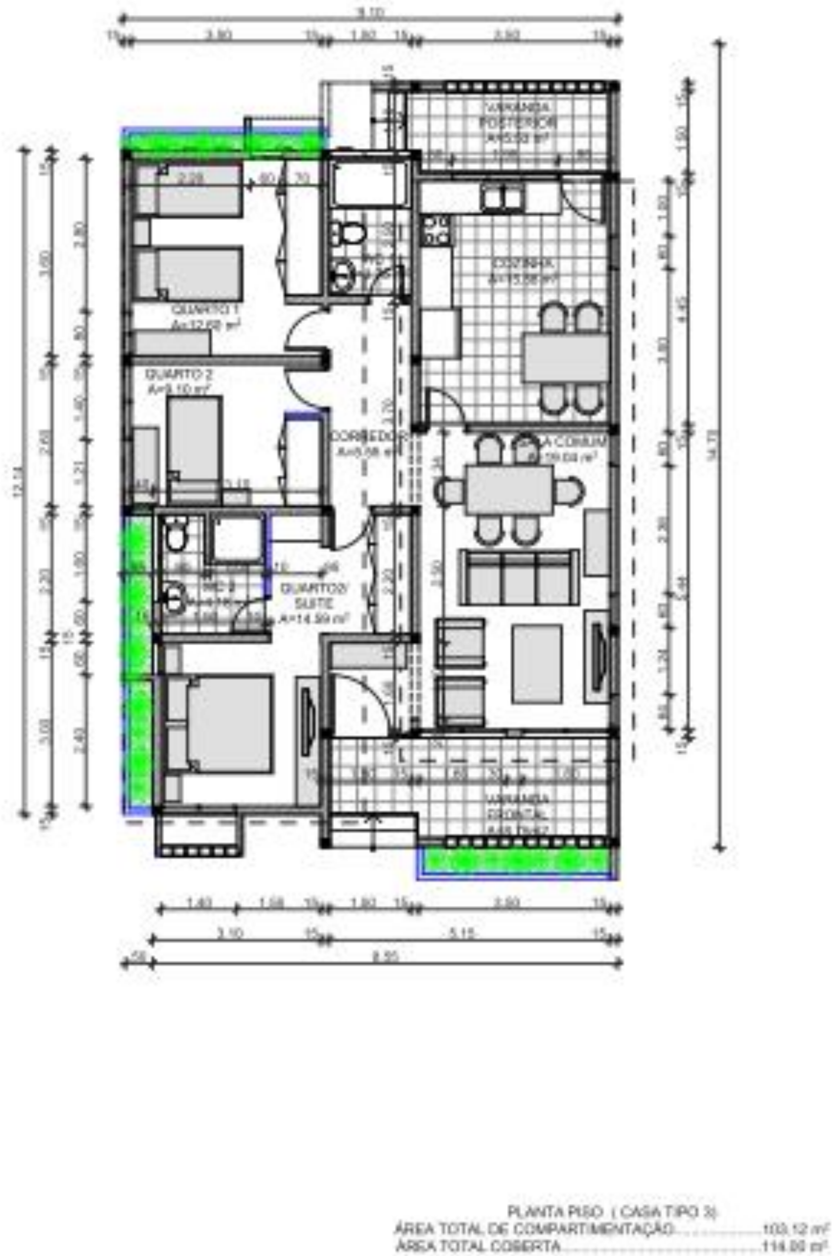

Figure H 2: Blue print of a type 3 energy efficient house.

Appendix I: LCC for the energy efficient house – excluding appliances improvements

Table I 2: Data summary for LCC for type 2house that includes only building's envelope energy efficient.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house acquisition	2,134,458.25	equal to the initial investment	2,134,458.25
2	Initial Investment for Appliances	121,166.00	equal to the initial investment	121,166.00
3	Total Initial Investment	2,255,624.25	-	2,255,624.25
4	Appliances Replacement 1(constant escalation rate of 2.6%)	121,166.00	6.96	842,723.33
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	121,166.00	10.42	1,262,706.39
6	Appliances Replacement 3(constant escalation rate of 2.6%)	121,166.00	12.15	1,472,010.87
7	Appliances Replacement 4(constant escalation rate of 2.6%)	121,166.00	13.01	1,576,320.71
8	Annual Electricity bill: 14,747kWh at 3.03MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	44,683.41	5.96	266,399.53
9	Annual Electricity bill: 14,747kWh at 5.31*MT/kWh (constant price during the remaining 44 years)	78,306.57	9.85	771,248.35
10	Maintenance cost (constant escalation rate of 2.6%)	42,689.17	13.44	573,683.87
11	Residual Value	(164,235.84)	0.01	(1,399.05)
12	Total LCC (MT)			9,019,318.24

Table I 3: Data summary for LCC for type 3 house that includes only building's envelope energy efficient.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house acquisition	3,247,359.50	equal to the initial investment	3,247,359.50
2	Initial Investment for Appliances	147,000.00	equal to the initial investment	147,000.00
3	Total Initial Investment	3,394,359.50	-	3,394,359.50
4	Appliances Replacement 1(constant escalation rate of 2.6%)	147,000.00	6.96	1,022,401.74
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	147,000.00	10.42	1,531,930.07
6	Appliances Replacement 3(constant escalation rate of 2.6%)	147,000.00	12.15	1,785,860.70
7	Appliances Replacement 4(constant escalation rate of 2.6%)	147,000.00	13.01	1,912,410.61
8	Annual Electricity bill: 19,217kWh at 2.94MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	56,497.98	5.96	336,837.21
9	Annual Electricity bill: 21,545kWh at 5.15MT/kWh (constant price during the remaining 44 years)	98,967.55	9.85	974,740.18
10	Maintenance cost (constant escalation rate of 2.6%)	64,947.19	13.44	872,801.23
11	Residual Value	(249,868.00)	0.01	(2,128.51)
12	Total LCC (MT)			11,829,212.71

Appendix J: Energy consumption for energy efficient houses considering 50% improvements over appliances

Table J 2: Energy consumption for energy efficient houses considering 50% improvements over appliances.

Type of appliances	F1*	F2*	F3*	F4*	Operational time (h)	Suggested time (h)	F5* (W/h)	F6* (W)
Freezers	1	1	189.0	150.0	16	16	3,024.00	2,400.00
CFL	11	12	19.5	16.0	9	5	1,072.50	960.00
Incandescent	0	0	-	-	0	0	-	-
Televisions	2	3	98.0	83.0	9	9	1,764.00	2,241.00
Electric Geysers	1	1	826.5	1,178.5	13	2	1,653.00	2,357.00
Stoves	1	1	878.5	1,472.5	3	3	2,635.50	4,417.50
Kettles	1	1	763.0	756.5	1	1	763.00	756.50
Ironing Machine	1	1	581.0	571.0	1	1	581.00	571.00
DVD	1	1	24.0	19.0	3	3	72.00	57.00
Air conditioning	1	2	851.5	849.5	8	3	2,554.50	5,097.00
Fans	2	2	60.0	51.0	6	3	360.00	306.00
Microwave	1	1	705.5	630.5	1	1	705.50	630.50
Refrigerator	1	1	207.0	290.5	16	16	3,312.00	4,648.00
Sound amplifiers	1	1	26.0	48.0	4	4	104.00	192.00
Radios	1	1	24.5	33.5	4	4	98.00	134.00
Space heaters	1	1	685.0	1,087.5	1	0	-	-
Other appliances					0		-	-
Computers	1	1	256.5	209.5	4	4	1,026.00	838.00
Toasters	1	1	252.5	361.5	3	3	757.50	1,084.50
Total W/h/day							20,482.50	26,690.00
Total kW/h/day							23.44	29.92
Total Kwh/year							7,373.70	9,608.40

*Note: F1=Appliances Quantity in type 2 houses, F2=Appliances Quantity in type 3 houses, F3=Appliances Power Capacity in type 2 houses, F4=Appliances Power Capacity in type 3 houses, F5=Total energy consumed for an energy efficient house - type 2, F6=Total energy consumed for an energy efficient house - type 3.

Appendix K: Estimated cost for energy efficient appliances.

Table K 1: Estimated cost for energy efficient appliances.

Type of appliance	I1*	I2*	I3*	Total cost	I4*	I5*	I6*	Total cost
Freezers	189	1	45,000.00	45,000.00	150	1	52,500.00	52,500.00
CFL	19.5	11	159.00	1,749.00	16	12	225.00	2,700.00
Incandescent	0	0	-	-	0	0	-	-
Televisions	98	2	7,500.00	15,000.00	83	3	10,500.00	31,500.00
Electric Geysers	826.5	1	10,500.00	10,500.00	1178.5	1	7,500.00	7,500.00
Stoves	878.5	1	15,000.00	15,000.00	1472.5	1	12,000.00	12,000.00
Kettles	763	1	2,250.00	2,250.00	756.5	1	2,250.00	2,250.00
Ironing Machine	581	1	2,250.00	2,250.00	571	1	2,250.00	2,250.00
DVD	24	1	3,000.00	3,000.00	19	1	3,750.00	3,750.00
Air conditioning	851.5	1	15,000.00	15,000.00	849.5	2	15,000.00	30,000.00
Fans	60	2	1,500.00	3,000.00	51	2	2,250.00	4,500.00
Microwave	705.5	1	7,500.00	7,500.00	630.5	1	7,500.00	7,500.00
Refrigerator	207	1	10,500.00	10,500.00	290.5	1	10,500.00	10,500.00
Sound amplifiers	26	1	9,000.00	9,000.00	48	1	7,500.00	7,500.00
Radios	24.5	1	1,500.00	1,500.00	33.5	1	1,050.00	1,050.00
Space heaters	685	1	15,000.00	15,000.00	1087.5	1	15,000.00	15,000.00
Other appliances			-	-			-	-
Computer	256.5	1	22,500.00	22,500.00	209.5	1	27,000.00	27,000.00
Toaster	252.5	1	3,000.00	3,000.00	361.5	1	3,000.00	3,000.00
Total cost				181,749.00				220,500.00

*Note: I1=power capacity (type 2 house), I2= type 2 house (appliances quantity), I3= estimated cost, I4= power capacity (type 3 house), I5= type 3 house (appliances quantity), I6= estimated costs.

Appendix L: LCC calculation type 2 and 3 houses – Considering 50% improvements over appliances power capacity and adoption of building energy efficiency strategies.

Table L 1: LCC of an energy efficient house type 2, considering 50% improvements of the appliances power capacity.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house acquisition	2,134,458.25	equal to the initial investment	2,134,458.25
2	Initial Investment for Appliances	181,749.00	equal to the initial investment	181,749.00
3	Total Initial Investment	2,316,207.25	-	2,316,207.25
4	Appliances Replacement 1(constant escalation rate of 2.6%)	181,749.00	6.96	1,264,084.99
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	181,749.00	10.42	1,894,059.58
6	Appliances Replacement 3(constant escalation rate of 2.6%)	181,749.00	12.15	2,208,016.30
7	Appliances Replacement 4(constant escalation rate of 2.6%)	181,749.00	13.01	2,364,481.06
8	Annual Electricity bill: 7,373.70kWh at 3.03MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	23,445.23	5.96	139,778.91
9	Annual Electricity bill: 7,373.70kWh at 5.31*MT/kWh (constant price during the remaining 44 years)	39,154.35	9.85	385,634.64
10	Maintenance cost (constant escalation rate of 2.6%)	42,689.17	13.44	573,683.87
11	Residual Value	(164,235.84)	0.01	(1,399.05)
12	Total LCC in (MT)			11,144,547.55

Table L 2: LCC of an energy efficient house type 3, considering 50% improvements of the appliances power capacity.

Item	Description of the Costs (1)	Estimated Cost at the reference Point (2)	Discount Factor (3)	Present Value (4) = (2)x(3)
1	Initial Investment for house acquisition	3,247,359.50	equal to the initial investment	3,247,359.50
2	Initial Investment for Appliances	220,500.00	equal to the initial investment	220,500.00
3	Total Initial Investment	3,467,859.50	-	3,467,859.50
4	Appliances Replacement 1(constant escalation rate of 2.6%)	220,500.00	6.96	1,533,602.61
5	Appliances Replacement 2 (constant escalation rate of 2.6%)	220,500.00	10.42	2,297,895.10
6	Appliances Replacement 3(constant escalation rate of 2.6%)	220,500.00	12.15	2,678,791.05
7	Appliances Replacement 4(constant escalation rate of 2.6%)	220,500.00	13.01	2,868,615.92
8	Annual Electricity bill: 9,608.40kWh at 2.94MT/kWh (considering an escalation rate of 9.8% during the first 6 years)	28,248.70	5.96	168,416.85
9	Annual Electricity bill: 9,608.40kWh at 5.15MT/kWh (constant price during the remaining 44 years)	49,483.26	9.85	487,365.02
10	Maintenance cost (constant escalation rate of 2.6%)	64,947.19	13.44	872,801.23
11	Residual Value	(249,868.00)	0.01	(2,128.51)
12	Total LCC (MT)			14,373,218.76