University of Pretoria

Influence of carbon tax on office buildings in South Africa

by

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Thesis submitted in complete fulfilment of the requirements for the degree of

PhD Quantity Surveying

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Department of Construction Economics

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Date: 07 July 2024

Declaration

I, the undersigned, hereby confirm that the attached thesis is my own work and that any sources are adequately acknowledged in the text and listed in the bibliography.

I accept the rules of the University of Pretoria and the consequences of transgressing them.

This thesis is submitted in complete fulfilment of the requirements for the degree of PhD Quantity Surveying at the University of Pretoria. It has not been submitted before for any other degree or for examination at any other University.

Signature of acceptance and confirmation

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Date: 07 July 2024

Abstract

Title of thesis:	Influence of carbon tax on office buildings in South Africa
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Greenhouse gasses (GHGs) contribute to global warming and climate change. Countries are combatting climate change and its negative impacts by significantly reducing their GHGs and are moving toward zero-carbon environments. Countries must adopt greener building technologies, design and construct net zero-carbon buildings and implement carbon taxes to combat the effects of climate change.

The most efficient way to eliminate or reduce GHG emissions is to implement a carbon tax. The Carbon Tax Act (Act No. 15/2019) of South Africa (SA) was only introduced in 2019 and with this recent introduction, there is limited information available regarding its impact on office buildings in the country. The influence of the carbon tax on developers who own both new and existing office buildings in SA is currently unknown.

The mixed-method approach with prescriptive analysis was used as a research method and data was obtained from structured interviews and a comprehensive literature review to design a SA carbon efficient office building model promoting carbon emission savings.

Data was collected where the interview responses and previous Project studies of EDGE were entered into recruitment logs to successfully track the data and the use of the EDGE application. All commercial property developers were approached to be part of the study as they play an integral role in the development of existing and new commercial buildings in SA.

With only a few available guidelines or no proper model specific to SA's climate conditions that could be followed by developers to develop or refurbish commercial buildings to be carbon neutral or net zero.

However, there was not a proper model specific to SA's climate conditions that could be used by developers to assist them in developing more sustainable buildings. The study findings indicate that the office building model designed for SA optimises energy efficiency, contribute to long-term cost savings for developers and reduces the impact of the carbon tax payable on office buildings that they can use.

Recommendations include for the further exploration of study are to assess SA's ability to meet the 2030 and 2050 net zero targets, the cost to become net-zero compliant and identify potential gaps in administering carbon tax and carbon credits.

Keywords: carbon tax, net zero buildings, developers, commercial buildings, office buildings

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I express my deep appreciation to my father, whose unwavering beliefs made my studies possible. Although you are no longer with us, I hope that you can witness from Heaven the dedication I have put into making you proud.

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List of Acronyms/Abbreviations

Term	Acronym/Abbreviation
AHU	air handling units
BEES	Building for Environmental and Economic Sustainability
BIPV	building-integrated photovoltaics
BKD	brick kiln dust
CCC	Construction Climate Challenge
COAS	carbon offset administration system
DEAT	Department of Environmental Affairs and Tourism
DPWI	Department of Public Works and Infrastructure
EBIT	Faculty of Engineering, Built Environment & Information Technology
EDGE	Excellence in Design for Greater Efficiencies
EPPF	Eskom Pension and Provident Fund
EPS	expanded polystyrene
ESG	environmental, social and governance
ETS	emissions trading system
GBC(s)	green building council(s)
GBCSA	Green Building Council of South Africa
GDP	gross domestic product
GHG	greenhouse gases
HR	human resources
IFC	International Finance Corporation World Bank Group
LCA	life cycle assessment
low-E	low emissivity
MTC	mass timber construction
National Treasury	National Treasury of the Republic of South Africa
NDC	nationally determined contribution
NDP	National Development Plan
NHFC	National Housing Finance Corporation
NZGBC	New Zealand Green Building Council
QS(s)	quantity surveyor(s)
PFA	pulverised fuel ash
PV(s)	Photovoltaic(s)
RICS	Royal Institution of Chartered Surveyors
SA	South Africa(n)
SANS	South African National Standards
SARS	South African Revenue Service
SRI	solar reflectance index
SSIC	Site Solution Innovation Centre
Stats SA	Statistics South Africa
UP	University of Pretoria

USA	United States of America
VRF	variable refrigerant flow
VRV	variable refrigerant volume
WorldGBC	World Green Building Council
WWF	World Wide Fund for Nature
XPS	extruded polystyrene insulation

List of Definitions

Term	Definition
Building for Environmental and Economic Sustainability (BEES)	BEES technology is a tool used to measure the performance of building products in the environment by conducting a life-cycle assessment (National Institute of Standards and Technology, 2020).
Carbon emissions	Carbon emissions are gases that absorb and re-emit heat into the atmosphere which results in the atmosphere being warmer than it normally is causing global warming and climate change (Brander, 2023).
Carbon sequestration	Carbon sequestration is the process of capturing, storing and transferring carbon emissions to reduce the amount of carbon in the atmosphere (Lal, 2007).
Class A offices	Class A offices are prestigious buildings located in areas with numerous amenities. These buildings are constructed using high-quality materials and methods that attract reputable tenants and have high rental rates (Boma Quebec, 2020).
Climate change	Climate patterns are shifting in the long-term at global and regional levels. This term refers to the increase in temperature on a global scale from the mid-twentieth century to the present (World Wide Fund for Nature [WWF] South Africa, 2019).
Excellence in Design for Greater Efficiencies (EDGE)	EDGE software was created by the International Finance Corporation (IFC, 2024) that is free to users and is a green building standard and international zero-carbon building certification system. This software is used to calculate the embodied and operational carbon emissions by entering data of the existing or new project into the system. This software assists in helping the professional team design a building that emit less carbon emissions.
Embodied carbon	Embodied carbon are the greenhouse gas (GHG) emissions created during the manufacturing; transportation; use; maintenance, replacement and deconstruction of construction materials, as well as during the end-of-life of a building (Lützkendorf & Balouktsi, 2022).
Evapotranspiration	Evapotranspiration is the combined processes of plant and soil surface evaporation and transpiration through plant shelters. This process entails the transfer of water from plant and soil surfaces into the atmosphere in the form of water vapour (Irmak & Haman, n.d.).
High-performance glazing	High-performance glazing decreases the entry of heat and optimises energy efficiency while enhancing daylight penetration (Indian Green Building Council, n.d.).
Life cycle assessment (LCA)	LCA is when the inputs and outputs of the environment, and the possible impacts on the environment of a construction material, service or product are calculated and assessed (Department of Environmental Affairs and Tourism [DEAT], 2004).
Load shedding	Load shedding is a process that is controlled where the entire country lacks electricity. It is used to prevent South Africa (SA)'s electric power system from a total blackout (Matsheta & Sefako, 2023).
Webinar	A webinar is a seminar presented online in which facilitators and participants communicate through the Internet (with or without a web camera) at any geographic location (Gegenfurtnera & Ebner, 2019).

CHAPTER 1: INTRODUCTION

1.1 Background Information

1.1.1 Introduction

Although climate change is not a new term in South Africa (SA), it has been disregarded by some South Africans. The debate regarding global warming and climate change has raised many concerns over the past few years and is now becoming a reality that needs to be addressed. Many South Africans are already experiencing the impact of climate change, and everyone must reduce their carbon emissions (WWF South Africa, 2019). Net zero and net positive buildings appeared to be a distant reality, allocated toward the type of projects that were experimental or yet to be researched (Green Building Council of South Africa [GBCSA], 2019).

Inspirations and inventions such as the PassivHaus and Living Building Challenge, have drawn attention to net-positive and net-zero buildings in the residential and commercial sectors. However, these types of inspiration and the importance of net-positive and net-zero buildings have not reached the point where they have seen a large-scale global uptake. The GBCSA (2019) explains that green building rating tools are not widely used. The number of buildings that reduce their energy consumption and carbon emissions are insufficient to reduce the global average temperature rise.

Currently, some developers are implementing existing approaches (e.g., green building measures), but not carbon efficient buildings in SA. This indicates that there is currently limited knowledge and studies undertaken on carbon efficient buildings and construction methods in SA. The Climate Action Tracker (2023) supports this by stating that there is a lack of information due to the country's preliminary nature to implement its net zero-targets as seen in Figure 1.1.

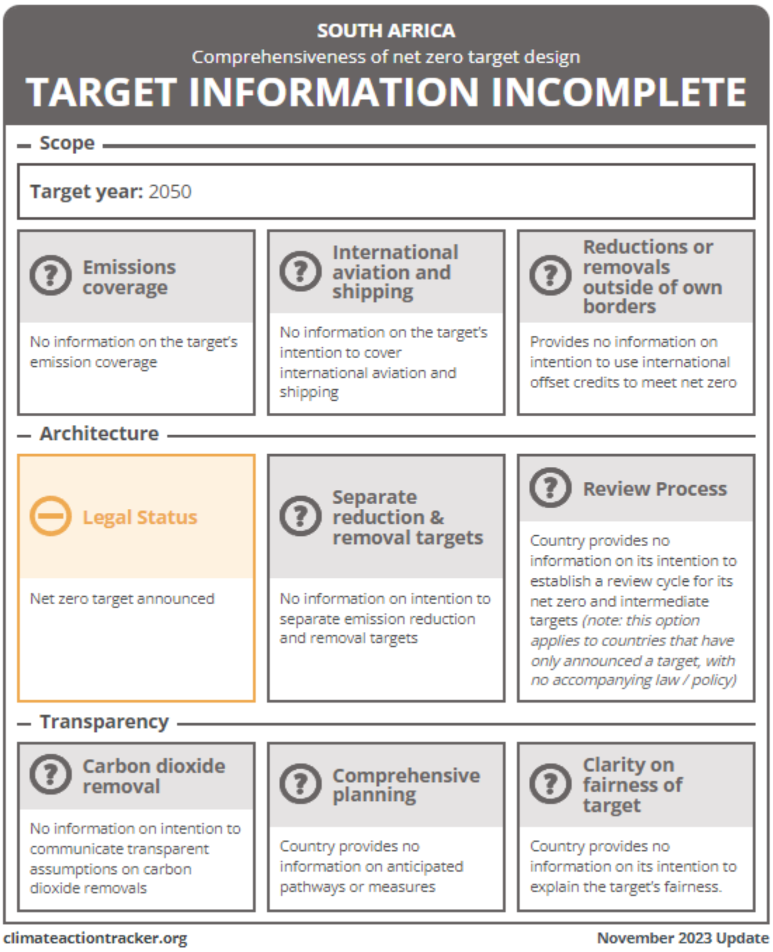

Figure 1.1: SA's net zero target information (Climate Action Tracker, 2023)

The SA Carbon Tax Act (Act No. 15/2019) was only introduced in 2019 and was accepted by economists as an economically efficient and cost-effective way to reduce carbon emissions (WWF South Africa, 2019). With the recent introduction of this tax, there is limited information available regarding its impact on office buildings in the country.

The most efficient way to eliminate or reduce GHG emissions is to implement a carbon tax (Oxford, 2019). Furthermore, Oxford (2019) explains that introducing a carbon tax is "the single most effective mitigation instrument" for reducing carbon emissions, as it motivates people to reduce their energy consumption, use cleaner fuels, and find alternatives for building materials in the construction industry.

This motivates the study of the influence of carbon tax in SA to conclude whether net zero-buildings will be a reality, how developers and property owners will respond to paying carbon tax or if they will convert their buildings into net zero-buildings to avoid paying tax, as well as identifying what measures can be taken to implement net zero-carbon.

1.1.2 Study Background

The New Zealand Green Building Council (NZGBC) (2019) explains that there is momentum worldwide of countries and organisations committing to being net zero-carbon rated by 2050, in alignment with the Paris Agreement of 2015. It has marked the start of something new and it is the most important race of the current generation's existence. A race to flatten the curve of rising global greenhouse gas (GHG) emissions, so that the rise in global temperature remains below 2 °C (Laski & Burrows, 2017).

The Paris Agreement is a milestone environmental accord adopted by most nations in 2015 to combat climate change and its negative impacts. The aim is to lower global GHG emissions to 2 °C above pre-industrial levels to limit the global temperature increase during this century (Denchak, 2018). While simultaneously pursuing to limit the global temperature increase to 1.5 °C. This Agreement included all major emitting countries committed to cutting the pollution that led to climate change and strengthening their commitment over time. The USA withdrew from the Paris Agreement in 2020, claiming that it is restricting the country while empowering others (Zhang, Chao, Zheng & Huang, 2017). In 2021, the Biden administration decided to rejoin the Paris Agreement at the start of their term. The Agreement is a pathway for developed nations to assist developing nations with their climate reductions and efforts to adapt. It provides a framework for clear reporting, monitoring and increasing the collective and individual climate goals of respective countries (Denchak, 2018).

Furthermore, the Paris Agreement is a thirty-two-page document where a framework is established for global climate action, including support for developing nations, reduction and adaptation to climate change, as well as explicit reporting and strengthening of climate goals.

One hundred and ninety-six countries, including New Zealand have agreed to cut their GHG emissions and consistently maintain the increase in the global average temperature below 2 °C above the pre-industrial levels. Some countries are aiming to cut their emissions at a faster rate (NZGBC, 2019). Denchak (2018) states that the only major emitting countries which have not joined the Paris Agreement are Turkey, Iran and Russia.

The Paris Agreement aims to:

- Reduce GHG emissions to limit the global temperature rise;
- Provide a framework for accountability, transparency and achievement of more determined targets; and
- Encourage more support for climate change reduction and adaptation in developing nations (Denchak, 2018).

Laski and Burrows (2017) state that there is a timeline for how quickly the world must change its course so that all major business sectors will operate in a state of zero-carbon emissions by 2050. Furthermore, approximately 30% of global energy consumption and all associated GHG emissions are caused by the construction and building sectors. This sector must contribute to finding new solutions. Thus, the construction and building sectors must transform into zero-carbon-built environments.

Therefore, the World Green Building Council (WorldGBC) set the following goals:

- By 2030, all new buildings must be operating at net zero-carbon. The new standard business practice must be net zero buildings, so that there will be no need for major refurbishments.
- By 2050, all buildings (100%) must be operating at net zero-carbon. In addition, all refurbishments of existing buildings must be accelerated based on the current refurbishment rates, and must be completed to a net zero-carbon standard so that 100% of buildings in operation are net zero-carbon (Laski & Burrows, 2017).

It is a rare occurrence that there is consensus among most nations, indicating that leaders from all around the world agree that human behaviour drives climate change. There is a threat to the environment, and global action must be taken to stop it. To stop this threat, countries must have clear commitments to reducing emissions, and they must reinforce their actions over time.

1.2 Study Purpose

The construction and building industries could provide long-term environmental improvements when using a range of measures to reduce carbon emissions. In addition, this industry is unique, as it could create and influence behavioural changes at all stages of the supply chain (GBCSA, 2019).

Therefore, all relevant parties (i.e., developers, property owners, the professional construction teams and tenants) must be made aware of the risks of climate change and be motivated the change to net zero-carbon buildings as soon as possible before incurring expenses later on (e.g., for carbon tax or refurbishment).

1.3 Research Significance

The main focus of this study is to identify the influence of the carbon tax on developers who own new and existing office buildings in SA, especially the influence of this tax on developers and property owners with substantial property portfolios. Identifying the influence of carbon tax on office buildings contributes to examining the current state and situation of carbon tax in this country, as well as assisting developers; property owners and managers; and other stakeholders with strategies on how to reduce the impact of carbon tax on their buildings (e.g., strategies to convert existing buildings into zero-carbon buildings).

1.4 Problem Statement and Aims

1.4.1 Research Problem

With the recent introduction of this tax in South Africa, there is limited information available regarding its impact on office buildings in the country. Hence, this study primarily aims to assess the influence of the carbon tax on developers who own both new and existing office buildings in SA, with particular emphasis on those with substantial property portfolios.

The question statement is as follows:

What will the influence of carbon tax be on office buildings in South Africa?

Whether developers and property owners convert existing buildings into zero-carbon buildings or build new zero-carbon buildings, this will assist the GBCSA and SA government to reach the WorldGBC goals. The goals set out that all new buildings must operate at net zero-carbon in 2030, and 100% of all buildings must operate at net zero-carbon in 2050. It will serve as a guideline to assist all relevant parties in preparing them for the future of zero-carbon activities, whether it is transitioning to net zero-carbon buildings or being responsible for paying SA carbon tax on their carbon emissions.

This study’s scope will on both existing and new commercial buildings where embodied and operational carbon reduction strategies will be identified.

1.4.2 Research Aims and Objectives

This study aims to determine the influence of carbon tax on developers owning office buildings. In addition, to identify whether this tax will be sufficient motivation for developers and property owners (who own GHG-emitting office buildings) to transition to net zero-carbon buildings. Alternatively, the research will determine if the influence of the carbon tax is too late to make a difference in global warming.

The study objectives are to:

- Conduct a literature review to determine whether net zero-carbon buildings will become a reality and influence carbon tax in SA;
- Determine what the goals of the WorldGBC would mean for SA;
- Collect data on the current state of net zero-carbon office buildings and the carbon tax in SA;
- Collect data on the current state of net zero-carbon office buildings and the carbon tax implemented in other countries;
- Analyse the data collected to identify the influence of carbon tax on SA developers and property owners;
- Analyse whether SA developers will be resistant toward paying carbon tax,: and
- Determine what measures to take by creating a zero-carbon building model for new and existing office buildings that will lower the influence of carbon tax.

1.5 Research Questions

1.5.1 Research Questions

The research sub-questions are as follows:

1. Are net zero-carbon buildings a reality in SA?
2. Will developers resist paying a carbon tax or converting their buildings to net zero-carbon?
3. What measures should be taken to implement net zero-carbon in new and existing office buildings?

1.5.2 Hypotheses

Carbon tax is a tax used to discourage GHG emitters from emitting high amounts of carbon emissions or to pay a tax per 1,000 kg of carbon they are emitting.

Once carbon tax is implemented, it will influence developers' and building owners' decisions when refurbishing existing office buildings or building new office buildings to operate on a net zero-carbon capacity.

Currently, there is no exposure to zero-carbon buildings in SA. Implementing a carbon tax (specifically on office buildings), will contribute to accelerating the promotion of net zero-carbon buildings. The influence of the carbon tax on existing and new office buildings, which are not net zero-carbon, will be where developers and owners face taxes of ZAR 190 per 1 000 kg of carbon emissions emitted and embodied in the buildings (PricewaterhouseCoopers, 2023). This will result in significant annual costs for developers and owners. Therefore, they will be motivated to convert to net zero-carbon buildings and change their way of thinking towards new and existing office developments.

a) Are net zero-carbon buildings a reality in SA?

Net zero-carbon buildings are new buildings that are constructed from building materials which are low-carbon emitting materials or existing buildings refurbished to be energy efficient in their daily operations to be carbon zero or positive emitting buildings. Net zero-carbon buildings need to comply with certain requirements set out by the GBCSA and certified by following the rating tools. Net zero-carbon buildings are a reality for SA, where green technologies must be implemented to reduce the current load on the electrical grid and create sustainable buildings.

b) Will developers resist paying a carbon tax or converting their buildings to net zero-carbon?

Currently, in SA there is insufficient exposure to the public regarding net zero-carbon buildings and carbon tax to ensure that GHG emitters transition to net zero-carbon buildings in time (prior to or during construction or daily operation of buildings). With exposure only coming from the GBCSA and interested parties, not an adequate number of persons (e.g., investors, developers, owners, tenants or other stakeholders) are aware of the situation to ensure a mass drive towards a change to meet the 2030 and 2050 goals. Therefore, developers will resist, and SA might not reach the WorldGBC goals without promoting net zero-carbon buildings and implementing a carbon tax in time to ensure that all buildings are net zero-carbon buildings.

c) What measures should be taken to implement net zero-carbon in new and existing office buildings?

New office buildings need to be constructed and existing office buildings need to be refurbished to be energy efficient and net zero-carbon, which will contribute to high initial costs. Despite the high initial costs, developers and owners will not only save on carbon taxes but also on operating costs.

Measures to take include increasing window sizes to increase natural light and reduce electrical lighting in offices, using fresh air ventilation to reduce mechanical ventilation, and using photovoltaic (PV) systems in existing buildings. New buildings could be constructed from carbon-friendly materials, PV systems could be installed, more natural light could pass through larger windows, and natural air ventilation could be achieved.

1.6 Assumptions

This study assumes that reliable zero-carbon construction and carbon tax data could be sourced to indicate whether the SA construction sector is ready for a carbon tax and is able to transition to net zero-carbon buildings to meet the 2030 WorldGBC goals. It is assumed that all net zero-carbon and carbon tax consultants are knowledgeable and experienced in their field and competent to assist developers and building owners to convert their buildings into net zero-carbon buildings or to assist them in calculating and paying a carbon tax for the emissions they are responsible for. It is assumed that the construction industry (as a whole) will face the same issues. All parties involved from the idea to the close-out stage and future management of the building will be affected by this transformation:

- QSs must become experts in calculating future carbon tax emissions and providing cost advice;
- QS to understand design philosophies (passive and active designs) in Super Low Energy Buildings (SLEBs) and Net Zero Energy Buildings (NZEB);
- QS must understand and evaluate the cost benefit analysis on the choice of materials and affecting the Operational Carbon, as well as the cost thereof;
- Engineers and architects must work together on the design of low-carbon emitting building materials;
- Contractors must construct or install energy-efficient and low-carbon materials; and
- Tenants must be responsible for managing the building’s carbon emissions at regular intervals.

1.7 Limitations and Delimitations

This study’s limitations are as follows:

- The scope of the study will include for both new and existing commercial buildings;
- Structured interviews will be conducted with developers and/or property owners who own buildings which are affected by a carbon tax, as well as consultants specialising in net zero-carbon buildings and carbon tax. These property owners and consultants

might be hesitant or too busy to participate in this study which will lead to a smaller sample size;

- There is insufficient literature on net zero-carbon and carbon taxes on office buildings in SA;

The study's delimitations are as follows:

- This study will be conducted within three years;
- The study is limited to developers and/or property owners operating in Gauteng, SA, but some developers might have commercial buildings in other provinces and/or countries where a low-carbon economy has already been implemented;
- This study is limited to exploring only the impact of the first phase of a carbon tax on office buildings in SA;
- The study's focus is only on commercial buildings that emit carbon emissions, not on residential buildings or industrial warehouses;
- The focus will be to create a model for new and existing office buildings that have low carbon emissions which would reduce the carbon tax for developers and how carbon tax will influence developers if they do not decide to convert their office buildings to have low carbon emissions. Therefore, the study will not focus on the:
    - *Physical calculation of carbon tax*. The Carbon Tax Act (Act No. 15/2019) details how to calculate the carbon tax for different types of emissions.
    - *Physical calculation of carbon emissions*. The EDGE application calculates the carbon emissions for different types of buildings based on the data inserted.
    - *How the tax will be submitted to the South African Revenue Service (SARS)*. This is detailed by SARS on how developers and owners can submit their carbon tax reporting documents and the process involved.

1.8 Summary

Kane-Berman (2021) notes that: "A cry for survival comes from the planet itself, climate change is an existential threat to humanity". The world is moving to a potential 3 °C rise in the next 100 years, and more countries must see the urgency to become carbon-neutral. Prior investigations have confirmed that the temperature rose between 0.8 °C and 1.25 °C from the periods 1870 to 1899 and 2000 to 2010. This is more than what is expected for the temperature in SA and indicates that from 2010, the rise might have been greater (Figure 1.2).

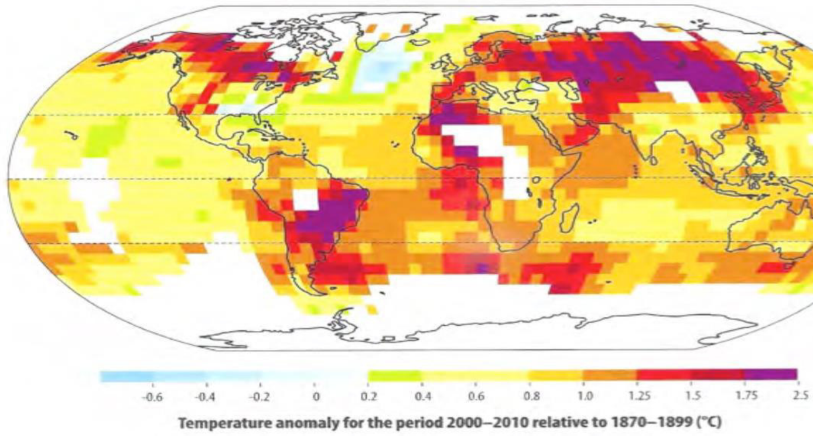

Figure 1.2: Temperature anomaly of the world (Sherratt, 2020)

Climate change needs to be addressed, and countries need to start moving towards a zero-carbon environment. The benefits of becoming a zero-carbon country will only be possible when buildings are zero-carbon, reducing GHG emissions and converting existing buildings to zero-carbon buildings as well as constructing new zero-carbon buildings (NZGBC, 2019). Another way to ensure zero-carbon-rated buildings is to apply a carbon tax through a fair and feasible transition to a low-carbon economy while ensuring sustainable growth in SA's economy (National Treasury of the Republic of South Africa [National Treasury], 2018). A carbon tax will play an essential role in achieving the objective set by the SA government to reach its commitment to cut GHG emissions.

Understanding the impact of a carbon tax on developers owning new and existing office buildings in South Africa involves examining whether net zero-carbon buildings are a reality in the country, assessing if developers would resist paying the carbon tax or convert their buildings to net zero-carbon, and identifying the measures necessary to implement net zero-carbon standards in new and existing office buildings. This analysis would help developers reduce the carbon footprint of their commercial properties.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

SA must realise the need to reduce carbon emissions and recognise the benefits of a low-carbon economy. The SA government has committed to reducing GHG emissions by 34% in 2020 and 42% by 2025 against the “a business as usual” curve (Legg, 2019). However, to achieve these kinds of reductions, frameworks, policies and financial instruments must be in place. Climate Action Tracker (2020a) indicates that SA is within the ‘fair’ range of the 2 °C goal in 2020. However, it is not coherent with the 1.5 °C long-term temperature goal of the Paris Agreement (Figure 2.1).

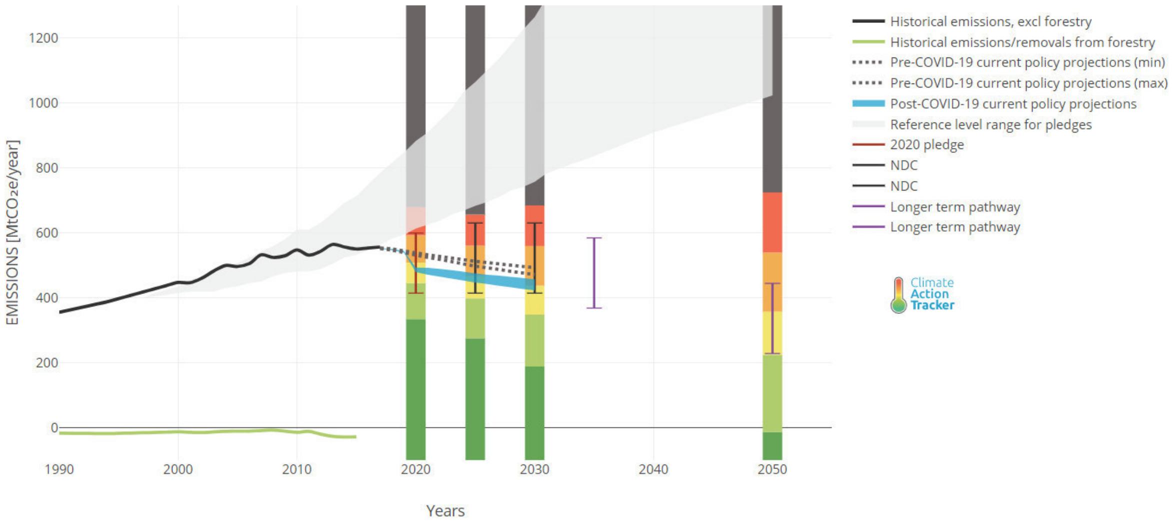

Figure 2.1: South African carbon emissions indicated per year (Climate Action Tracker, 2020a)

Due to the COVID-19 pandemic, SA’s social, health and economic challenges worsened since August 2020 due to the fifth highest infection rate of all countries. The SA government committed to focusing on carbon-intensive investments during the post-COVID-19 economic recovery period. This would create opportunities for implementing low-carbon technologies (Climate Action Tracker, 2020a). Climate Action Tracker (2020a) revealed that SA’s emissions were about 9% to 11% lower due to international trade and the domestic economy, which came to a standstill due to the lockdown implemented by the government to stop the spread of COVID-19. Climate Action Tracker (2020a) estimates that SA might reduce its emissions by 8% to 10% below the pre-COVID-19 projection, but the ultimate impact on emissions due to the COVID-19 pandemic remains undefined.

2.2 Climate Change and the Effect of the Construction Industry

Climate change is a reality and will only be mitigated if all countries act together to find ways to reduce their GHG emissions. Denchak (2018) believes that climate change will only be limited by “substantial and sustained reductions in greenhouse gas emissions”. The quality of using a single global temperature threshold to represent the dangers of climate change could be debated. However, it is believed that any increase in global temperatures of more than 2 °C is an intolerable risk. This might result in more severe droughts (as seen with the low rainfall in Australia that led to severe bushfires in 2019), hurricanes (the number of tropical storms and hurricanes has increased over the last decade), mass extinctions, and the drastic melting of Arctic ice (Katz, 2019). It is uncertain how much change in the climate will “trigger abrupt and irreversible changes” in the Earth’s systems. However, the risk of exceeding this threshold increases only with rising temperatures (Denchak, 2018). Denchak (2018) emphasises that global action needs to be taken to avoid significant changes in current lifestyles. Therefore, the goal is set by the Paris Agreement to cap the global warming rise to only 1.5 °C, where a very small difference between 1.5 °C and 2 °C might have a great impact on the environment.

SA might be a considerable global emitter of GHGs as the country relies on fossil fuel-based energy. The country has a dual responsibility to reduce its GHG emissions by following the National Development Plan (NDP) and honouring its international emission reduction commitments (Duncan, 2019). Therefore, it is essential to examine the influence of carbon tax on office buildings when SA honours its commitments by:

- Highlighting the importance of its GHG emissions;
- Encouraging the construction and building sector to use green building materials; and
- Motivating the construction of zero-carbon buildings to reach the goals set by the worldgbc for 2030 and 2050.

2.3 Resistance to Change

Mishra and Isazada (2021) state that change cannot be avoided in today’s world of uncertainty, complexity, ambiguity and instability. The problem is when change initiatives are met with resistance from companies. When companies are content in their current state of operation, the probability of resistance is higher. Although resistance cannot be ignored, Mishra and Isazada (2021) note that there are methods to minimise it. Change involves many unknowns, and creates anxiety, fear, ignorance and bias, leading to resistance. Familiarity is a comfort zone where some companies prefer to be, as they fear the unknown, increasing the likelihood that reasons for change will be sabotaged or ignored.

Although resistance to change can be expected, there are ways in which it could eliminate some unknowns and contribute to success:

1. Identify the reason for the change and summarise all the consequences of the inaction;
2. Adopting a single change sequentially and creating desire; and
3. Change methods must be treated as official projects in which constant support and communication are key.

Other changes can be navigated better with fewer obstacles when successful projects are achieved.

2.4 Net Zero-Carbon Buildings

2.4.1 Building Importance

Buildings play a large role in countries with a low-carbon economy. The NZGBC (2019) mentions that the operation and construction of buildings are responsible for 20% of domestic emissions which is the net of emissions from traded goods. Half of the 20% of domestic emissions are from the construction of infrastructure and buildings, and the other half are from building operations. Many businesses that own or lease buildings generate a significant proportion of emissions, and the central focus must be on mitigating GHG emissions. To reduce these emissions, certification must be put into place so that buildings can achieve net zero-carbon. To achieve the goals of WorldGBC, there must be a swift change in every country's current market state, and it must ensure that 100% of all buildings are net zero-carbon rated by 2050. Laski and Burrows (2017) note that each country must ensure that every building built must be net zero-rated as soon as possible. Carbon emissions might have a critical impact on financial, environmental and societal effects (Royal Institution of Chartered Surveyors [RICS], 2017). Mitigating carbon emissions limit the depletion of resources and minimises pollution. There is an urgency to address the need for the quick growth of carbon-intensive building investments, especially in developing countries (GBCSA, 2019) (Figure 2.2).

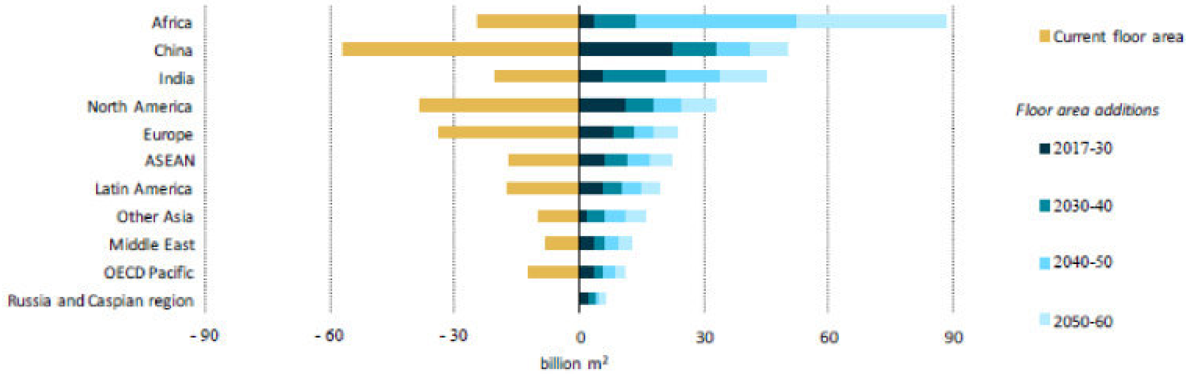

Figure 2.2: Floor area additions of countries (Green Building Council South Africa, 2019)

Figure 2.2 shows the details of how each key country might expand or add to its floor area by 2060. Africa is expected to expand its floor area by 2060, meaning that there is potential to develop and construct buildings that are either environmentally-friendly or environmentally-damaging. In its NDP Vision 2030, SA set out a detailed plan to: "Progressively strengthen the energy efficiency criteria set out in the South African National Standard 204 to achieve a zero-carbon building standard by 2030" (GBCSA, 2019).

New Zealand, among other countries (including SA), has released a set of tools that assist building owners in managing, measuring and offsetting their emissions so that they can become net zero-carbon by 2050. These sets of tools are designed and managed by each green building council (GBC) of its country under the leadership of WorldGBC. Therefore, the WorldGBC has set milestones for both existing and new buildings to ensure that there would be progress towards 2050 goals at a global level. Figure 2.3 shows the anticipated trajectory set out by WorldGBC for all new buildings to be net zero-carbon rated by 2030.

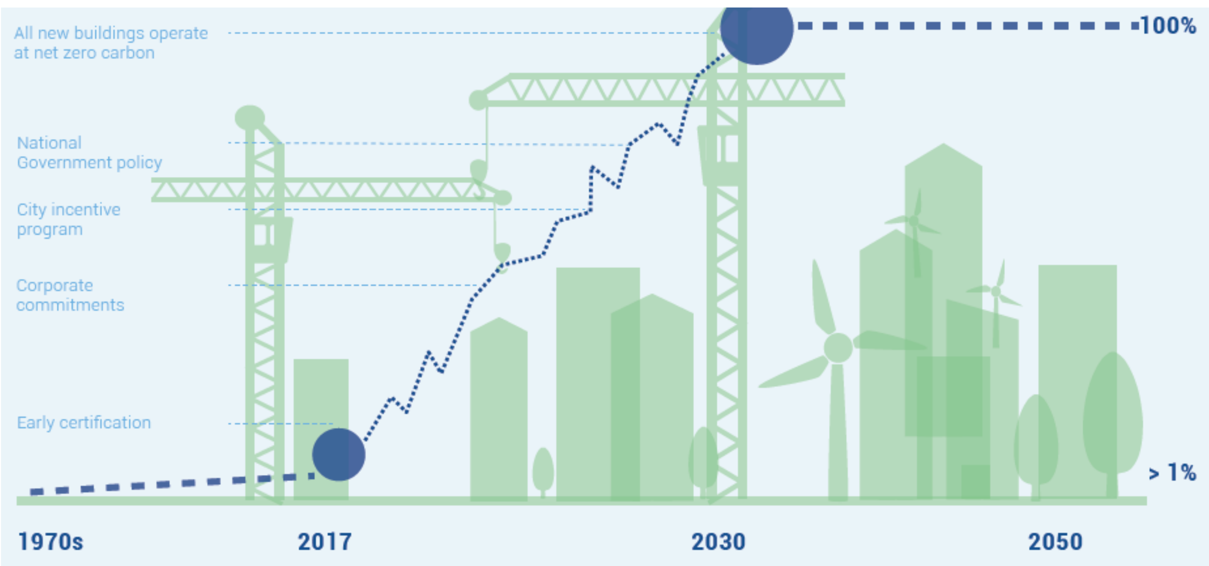

Figure 2.3: New buildings to operate at net zero-carbon from 2030 (Laski & Burrows, 2017)

The anticipated trajectory, as per the milestone of the WorldGBC, is that 100% of all buildings must be net zero-carbon by 2050 (Figure 2.4).

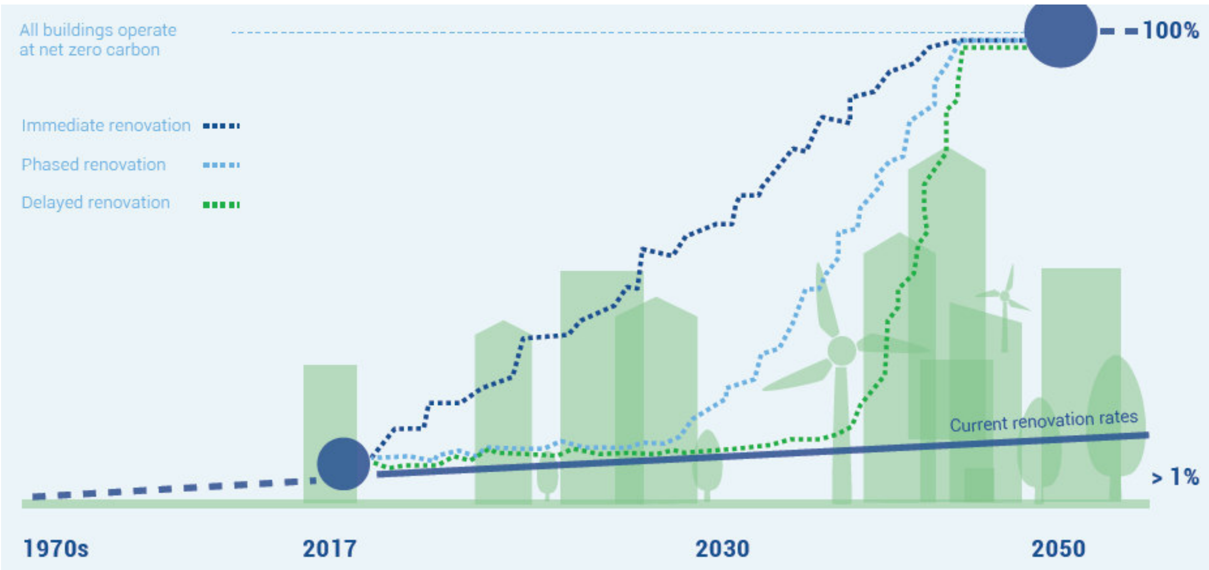

Figure 2.4: One hundred per cent of buildings to operate at net zero-carbon from 2050 (Laski & Burrows, 2017)

RICS (2017) notes that the built environment is responsible for a large amount of carbon emissions which are attributable not only to using built assets (e.g., operational emissions from commercial tenants), but also to the construction of commercial buildings in the form of embodied emissions. Operational emissions from a commercial building come from energy consumption by the end-user in their day-to-day operation of the commercial space, while embodied emissions result from procuring, producing and installing the materials and building components that create the structural envelope. These emissions include emissions throughout a building's lifetime due to repair work, maintenance, demolition, refurbishments and disposal (RICS, 2017). Operational emissions are already being addressed through reduction aims in building regulations, sustainable assessment rating schemes and planning requirements by local authorities.

However, RICS (2017) notes that embodied carbon emissions have not yet been addressed. To understand a commercial building's total carbon impact, it is necessary to assess the embodied emissions and anticipated operational emissions over the commercial asset's entire life.

This is done by taking the operational and embodied emissions into account over the commercial building's expected life cycle which represents the whole-life approach. The whole-life approach recognises the total combined opportunities that are best for mitigating lifetime emissions and preventing any unintended consequences of focusing on the operational emissions of commercial buildings only. For example, the burden of embodied carbon could be higher when installing a triple-glazing window rather than a double-glazed window compared to the operational advantage of the additional windowpane to integrate whole-life carbon into the sustainability agenda of a commercial building to achieve lower carbon emissions (RICS, 2017).

Figure 2.5 indicates the whole-life carbon emission breakdown for different building types in London which illustrates the relative weight of the embodied and operational carbon. A typical Category A commercial building comprises:

- Thirty-five per cent of embodied carbon emissions;
- Thirty-two per cent of operational carbon emissions;
- Eighteen per cent of regulated operational emissions; and
- Fifteen per cent of unregulated emissions.

Therefore, 85% of the carbon emissions can be accounted for, despite the 15% of unregulated operational emissions, which could be reduced or maintained in a commercial building. Considering this, the need for net zero-carbon buildings is essential to combat carbon emissions (Figure 2.5).

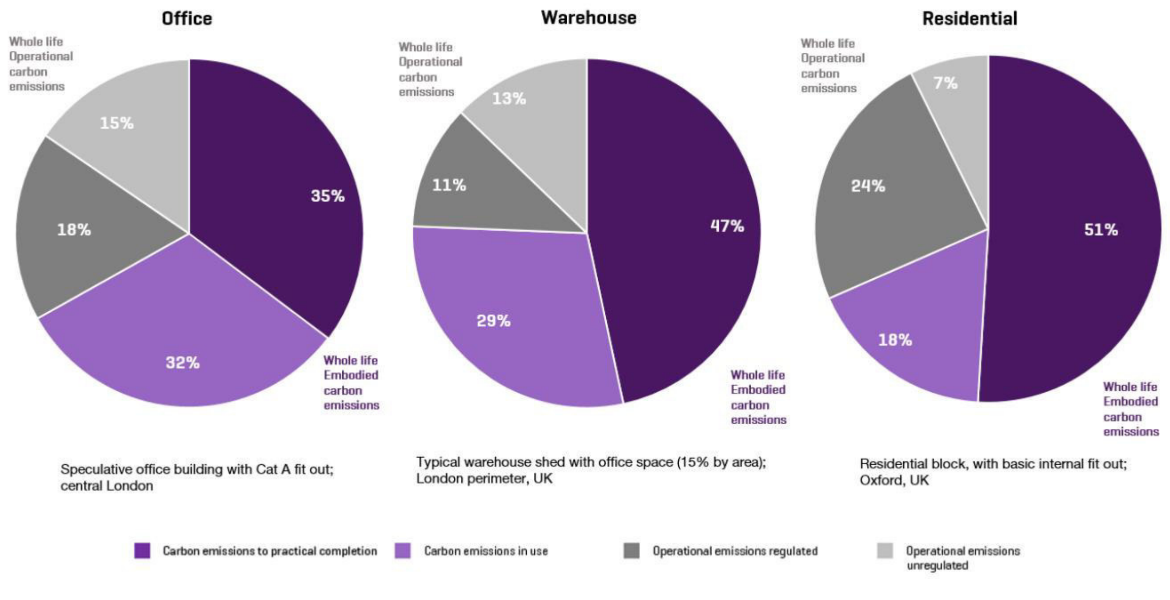

Figure 2.5: Total whole-life carbon emissions breakdown for office, warehouse and residential developments (Royal Institution of Chartered Surveyors, 2017)

2.4.2 Defining Net Zero-Carbon Buildings

In September 2016, 10 GBCs were assembled to support the drive to achieve net zero buildings in their markets as part of the WorldGBC-led project named “Advancing Net Zero”. Laski and Burrows (2017) mention that this project motivates national GBCs to develop their own net carbon certification and verification programmes. Key principles are agreed upon for net zero-carbon buildings by the GBCs that guide the development of certification schemes. As GBCs’ programmes evolve, the net zero-carbon definition and incorporating certain applications might be adapted or adopted as required by each country’s market concerning its specific regulatory, cultural, climatic and geographic conditions. A net zero-carbon building is defined as a building that is “highly energy efficient with all remaining energy from on-site and/or off-site renewable sources” ’(NZGBC, 2019). Furthermore, Laski and Burrows (2017) define net zero-carbon buildings as: “highly energy-efficient buildings, where all remaining operational energy use is from renewable energy, preferably being on-site but also off-site production to achieve net carbon emissions annually in operation”.

Laski and Burrows (2017) provide five key components of zero-carbon buildings (Figure 2.6):

- Reduce the demand for peak energy;
- Generate renewable energy;
- Have an embodied carbon metric;
- Have energy intensity metrics; and
- Lower its emissions.

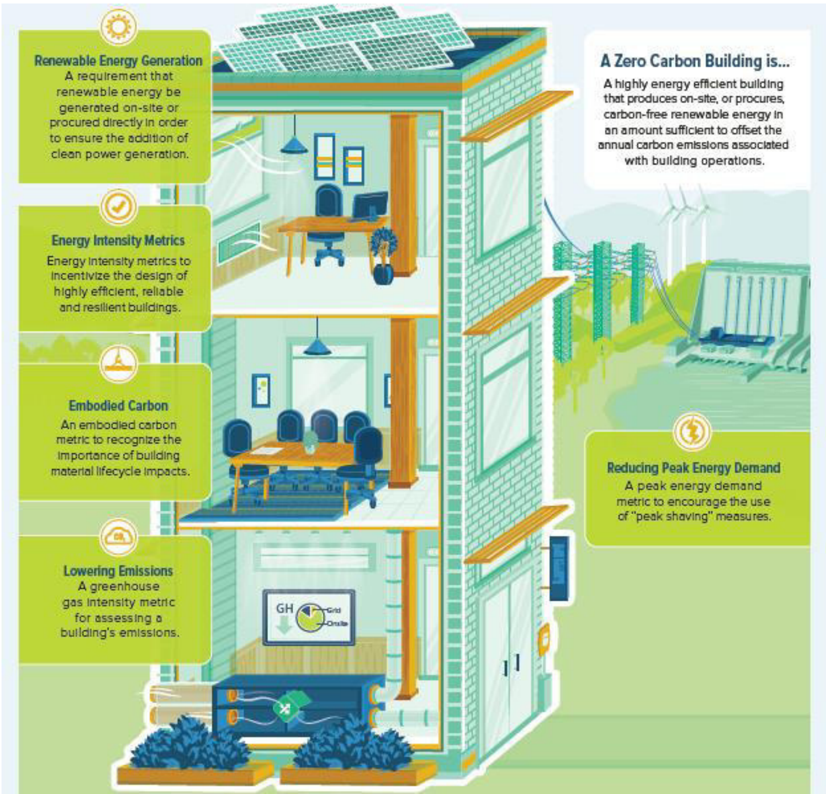

Figure 2.6: Five key components of a zero-carbon building (Laski & Burrows, 2017)

The Volvo Construction Climate Challenge (CCC) (2018) stated that building professionals must push for renewable energy production and energy efficiency of buildings to reduce the amount of carbon generated/emitted by fossil fuels used to operate buildings. The Vodafone Site Solution Innovation Centre (SSIC) is a flagship net zero-emission building in SA. This 4 125 m^2 building was constructed in 2011 in Midrand, SA (archiDATUM, 2023). Electrical, wet services and mechanical engineers worked together with a project team to design this innovative building. archiDATUM (2023) states that the building has 100% views of the external environment, and 90% of internal spaces have 250 lx daylight luminance and motion detection light sensors. High-performance glass, external shading devices, floor-level natural air ventilation, a solar absorption chiller, and 292 PV panels produce about 230 kWh of solar energy for the building, which is sufficient to feed surplus energy into the other buildings of Vodacom. Therefore, a zero-rated commercial building was created.

Savings in water use at the Vodafone SSIC were obtained using economical water fittings and fixtures. Grey water from sinks and wash hand basins and a rainwater harvesting system is treated using the wetland and for toilet flushing and irrigation (archiDATUM, 2023). Precast floor slabs (with no further floor coverings) were used for the floor construction, eucalyptus gum poles and steel (60% recycled) were used for the structural columns, and a timber beam system was used for the roof structure.

The concrete used had cement substitutes of about 60%, and a waste management and recycling system was used to minimise the waste transferred to dump sites. Figure 2.7 shows the elevations of the Vodafone SSIC, where the structural components can be identified.

Figure 2.7: Elevations of the Vodafone Site Solution Innovation Centre (archiDATUM, 2023)

2.4.3 Building Materials

Volvo's CCC (2018) notes that GHGs emitted during the process of making construction materials need to be considered before construction, commonly known as 'embodied carbon'. About 11% of total GHGs are emitted during the production of building materials. Although 11% might not seem much compared to operational energy which is 28%, when constructing new buildings, embodied carbon plays a role as much as renewables and energy efficiency. Furthermore, the Volvo CCC (2018) states that this is critical because the emissions that will be produced between now and 2050 will determine the effects that climate change has and whether SA will meet the agreed Paris Agreement goals.

First, the building materials or systems that would give rise to a building's embodied GHG emissions must be identified. Second, to obtain an idea of how one system or material will compare to another in a building project the whole-building life cycle assessment (LCA) should be used. The LCA reviews the multiple impacts of building materials (Volvo CCC, 2018). This includes the global warming potential over the product's entire lifespan (from extracting and manufacturing all the way through to the landfill and plant for recycling). Carbon impact experts in the construction industry have developed a LCA practice guide (Volvo CCC, 2018). The aim is to help construction consultants and professionals use software to obtain and interpret the results.

In SA, this can be done by examining the immediate impact of materials (e.g., steel, bricks, timber, concrete and corrugated roof sheeting) on GHG emissions to achieve a LCA for carbon emissions (Chemaly & Terreblanche, 2020). SA firms have committed to converting or constructing their existing and/or new projects into green buildings since 2015, which is a large shift towards sustainable construction, compared to other international countries.

Growthpoint Properties (2021) have committed to providing energy efficiency, green buildings, and sustainability to reduce GHG emissions emitted by buildings. Growthpoint aims to develop office buildings that achieve no less than a 4-Star Green Star SA rating based on GBCSA. Focusing on the green performance of existing office buildings, as well as the Energy and Water Performance Rating tool benchmark of the GBCSA. De Klerk (2023) states "We make a concerted effort to ensure our impacts are positive". Attacq Limited (2020) property development company stated that their outcomes include that their buildings have a minimal impact on the environment, to proactively reduce and control their carbon emission footprint from a truthful baseline, and to reduce the carbon footprint of their buildings.

However, many other projects or developers do not have the financial capacity to perform a full-scale whole-building LCA, but the Volvo CCC (2018) mentions that there are takeaways from this process which project consultants and teams can use in their everyday work without incurring additional costs, or sometimes without client buy-in or knowledge needed. One thing to take away from the whole-building LCA is that structural systems have the largest source of embodied carbon, amounting to about 80%, depending on the type of building. Volvo CCC (2018) suggests that the structural system needs to be targeted to reduce the embodied carbon in a project, which may comprise steel, concrete, and wood, and can be improved in different ways to minimise carbon emissions.

Chemaly and Terreblanche (2020) suggested a way to efficiently provide sustainable building materials by repurposing existing materials that are not limited to raw materials, which can help to reduce the waste in construction. However, the materials used in a country are influenced by policies, location, and availability, which are usually determined by the governing bodies that control the impact on the environment. The following materials have significant impacts on the environment and contribute to the embodied carbon in buildings.

2.4.3.1 Cement and Concrete

RICS (2017) states that building elements containing cementitious materials or lime, such as mortar and concrete, have the potential to absorb carbon dioxide (CO2) when exposed to air owing to the carbonation process.

Carbonation occurs when calcium oxide (CaO) reacts with calcium hydroxide ($Ca(OH)_2$) and CO_2 in the atmosphere. Concrete undergoes carbonation when left exposed on surfaces because it contains hydrated calcium oxides (RICS, 2017). Over the life of concrete elements, carbonation occurs and needs to be accounted for during the LCA. Carbonation rates are dependent on factors such as exposure duration, exposure conditions, concrete designation, and any concrete surface treatment. Because of the carbon-emitting process used to make cement, which is an important ingredient in concrete, concrete has a larger footprint. Portland cement manufacturing produces an estimated 5% of total global carbon emissions (Volvo CCC, 2018).

The cement industry is the third largest GHG emitter in the world (Rossi, 2019), accounting for 8% of global carbon dioxide emissions. However, its percentage is estimated to grow in the coming years due to rapid urbanisation and economic development that will continue across Sub-Saharan Africa and Southeast Asia. Rossi (2019) projects that the cement production by 2050 will increase by 23%. By 2030, a 16% reduction in cement-related emissions will be needed if countries want to meet the Paris Agreement target of staying below 2 °C. Sankovitz (2018) mentions that despite the negative impact that concrete has on the environment, there are some advantages (e.g., it requires little maintenance, it is durable, gains strength over time, and it can be formed into various shapes which are usually the cheapest option and consist of locally available raw materials).

Various alternatives are available for concrete:

- When supplemental cementitious materials (blast-furnace slag or fly ash) are used to replace cement, it provides a reduction of embodied carbon in concrete which is a go-to method that can be considered in projects. There are many ways to reduce the cement content (e.g., using less water content or specifying a higher-quality aggregate). Volvo CCC (2018) stated that the New Mexico City Airport project is a perfect example, where concrete mixes and efficient structural steel design helped reduce the total embodied carbon by 10% compared with a benchmark building. The reduction in embodied carbon amounted to 130 million kg of carbon, which is equivalent to removing 28 000 cars from the road for one year.
- Rossi (2019) mentions that New Jersey recently had a trial run of a new concrete-making process which was developed by Solidia Technologies. The most essential ingredient in concrete, cement, is tweaked by altering its curing process. Rossi (2019) stated that Solidia Technologies' aim is to substantially cut the carbon emissions associated in the production of cement while making the concrete cheaper than the traditional process.

Fossil fuels are normally burned to heat the kiln required for the high temperatures at which the materials break down. This thermal decomposition process releases carbon emissions. The process of thermal decomposition results in emissions where carbon is trapped in limestone and combines with oxygen in the air, creating a by-product of carbon dioxide. Rossi (2019) indicates that with the manipulated cement chemistry, the required kiln temperature is remarkably lowered to produce the cement clinker. Concrete curing is then performed using cement and waste carbon dioxide instead of water. Combined, these technologies produce a 70% reduction in the carbon footprint compared to Portland cement-based concrete at a lower cost.

Another suggested method is to pump carbon dioxide, which is liquefied, into wet concrete while it is being mixed, as developed by CarbonCure. Carbon from carbon dioxide reacts with concrete as it hardens, becoming a mineral which effectively reduces the need for cement without compromising the price and strength of concrete. An example of this product in use is a multi-storey commercial office building in Georgia that was set to be completed by the end of 2019. This was the first large-scale development that used the CarbonCure system in the whole structure, preventing more than 750 tons of carbon dioxide from being released into the atmosphere (Rossi, 2019).

Sankovitz (2018) adds that carbon sequestration is the process by which concrete absorbs carbon dioxide and permanently stores it. Depending on the specific mix of concrete (made from sand, cement, water, gravel, or rock), it absorbs at different rates. Sankovitz (2018) states that scientists normally assume that the quantity of carbon dioxide is minimal when concrete is removed from the atmosphere compared to the manufacturing thereof, but recent studies show that concrete buildings can offset their emissions. Concrete can emit 19% of carbon dioxide through its manufacturing process and can be re-absorbed throughout its lifetime.

A wide variety of techniques can be used to produce concrete, as there are 30 different theoretical concrete mixtures. However, there are only a limited number of techniques based on mixtures that are frequently used in building construction. Sankovitz (2018) explained that LCA's were conducted, considering the environmental impacts of all stages of a concrete's life (ranging from raw material extraction through cement processing, use, distribution, maintenance, and repair, as well as recycling or disposal). The LCA calculated the total carbon emissions from each concrete mixture and formulated the estimated total carbon sequestration. An important finding from this procedure is that stronger concretes have lower carbon emissions than weaker mixtures.

This estimation of carbon sequestration depends on engineering parameters; e.g., the shape of the concrete and the cement type used. Structural engineers and architects will need to make serious informed decisions regarding the specification and design of concrete mixtures while considering their environmental impacts.

There is still a long way to go. Sankovitz (2018) mentions that studies on low-carbon concrete are only the starting point for creating more environmental structures of concrete. Currently, a wide range of lower-carbon-intensive alternatives are being developed in laboratories around the world. Sadly, Rossi (2019) states that in the current market, there are major manufacturers that are cautious in making changes to their existing products. Strong policies to encourage green technologies are absent, and the construction industry is wary of novel building practices. Rossi (2019) stated the following: “The problem is that we have relied too long on prescriptive codes and standards that tell us to make concrete a certain way, rather than using performance-based criteria that would spur sectoral innovation”.

Another issue that arises is cost, where people are not willing to incur additional costs for new solutions. Rossi (2019) emphasised that there is a lack in policies that encourage investments into environmentally friendly cements, as well as offsetting the high costs. Advancements in technology cannot drive carbon emissions down on their own, as there needs to be measures in place, such as penalties to send marker signals and emission caps, or to encourage the adoption of greener technologies globally. Sankovitz (2018) states that new concrete alternatives could a long way to help maintain a vigorous built environment and improve the natural environment. Cement alone can make a difference to slow climate change, but the only way to achieve this is when the whole industry will accelerate its efforts. To avoid or delay this challenge is not an option (Rossi, 2019).

2.4.3.2 Steel

Horn, Loureiro, MacDonald and Vermilya (2018) states that reinforced steel has a high demand and contributes to a greater environmental impact. Compared to concrete, steel has a much larger embodied carbon footprint by weight, where 1 000 kg of steel equates to about 1 000 kg of GHG emissions. Steel production is responsible for 6.6% of global GHG emissions, which is much higher than that of Portland cement (Volvo CCC, 2018). During the manufacturing of reinforced steel, iron ore is heated using natural gas in a furnace until it is in liquid form. This is where roughly 70-80% of the total carbon dioxide emissions from steel production are released through carbon, which reacts with oxygen in the air to create carbon dioxide.

Furthermore, Horn et al. (2018) explains that as soon as iron is extracted from the raw ore, it is purified within a blast furnace where oxygen is blasted onto the hot iron to produce crude steel. Crude steel can be refined and given certain qualities depending on its future use. To give reinforced steel its extreme strength, it is pulled through small round openings that are round at high temperatures.

The extraction of raw materials needed to manufacture steel produces just as much carbon dioxide as steel. Horn et al (2018) found that the extraction process of raw materials, like 1 kg of iron ore which steel is made from, produces around 0.482 kg of carbon dioxide. Volvo CCC (2018) mentions that a large amount of reinforcement is used in concrete buildings, but 90-100% can be recycled steel. Companies use the Electric Arc Furnace technology to recycle steel. Recycled steel can be transformed into steel reinforcements (Chemaly and Terreblanche, 2020). The enclosure of a structural system can have a large embodied footprint that represents up to 15% of the global warming impact of a typical commercial building. Volvo CCC (2018) states that curtainwall systems have a large impact on climate change, as aluminium has very high embodied carbon and operational impacts. Therefore, it is advisable to reduce its use as much as possible.

Another method is to use mass timber construction (MTC) practices that use engineered wood products as the main source of structural material. MTC can be used for low-to medium-rise buildings in the private and public sectors (Horn et al. 2018). Australia is one of the countries that makes use of MTC practices using cross-laminated timber instead of reinforced steel and concrete, which minimises the GHG emissions of the Australian residential sector by up to 182% by 2050 (Horn et al., 2018). This is because steel and concrete which are normally used, are replaced with wood alternatives. Wood products have negative emission values owing to atmospheric carbon sequestration during the life cycle of trees.

2.4.3.3 Bricks

Brick manufacturing is one of the oldest processes and has been used since Before the Common Era. Today, bricks are used to construct buildings all over the world because of their ease of availability, handling, and low cost. Bricks were obtained when the clay was burned in a kiln. Abbas, Saleema, Kazmi and Munir (2017) explains that burnt clay bricks are produced by exposing a clay mixture through moulding, burning and sun drying processes. Riaz, Khitab and Ahmed (2019) states that the manufacturing process of bricks consumes a large quantity of good quality clay. Chemaly and Terreblanche (2020) adds that bricks are commonly used around the framework of the building, which includes the outer façade walls, strip footing walls, and internal dividing walls that may be load-bearing elements.

Bricks are commonly found in SA and are more commonly used. Cement blocks have about 1.5 times the embodied energy costs than a mudbrick and 1.7 times the carbon emissions. This choice of material affects the decision of materials used in buildings and influences the embodied energy of the building.

Bricks commonly used in SA are concrete blocks and fired clay bricks. Both have standard sizes but differ in terms of price. The clay bricks are 222 × 106 × 73 mm high between R2 and R4, depending on the quality, and the concrete blocks are 390 × 140 × 190 mm high between R9 and R11 (inclusive of value-added tax). Riaz et al. (2019) explains, one way to make bricks a sustainable material is to use brick kiln dust (BKD) as a replacement material. Bricks are prepared by combining waste materials, such as BKD. This produces a brick that has enhanced water absorption capability, lighter weight, high efflorescence resistance, and good insulation properties, but the mechanical strength is lower. Riaz et al. (2019) determined that by combining BKD into the manufacturing of clay bricks, it will be saving about 25% of fertile clay, as well as be environmentally beneficial and sustainable.

Another alternative way to make bricks more sustainable is to use Papercrete bricks. Delcasse, Rahul, Abhilash and Pavan (2017) believe that Papercrete bricks can be used as a sustainable building material. These bricks are made using recycled materials, thus creating low-cost materials. Papercrete bricks consist of recycled from used paper, cement (Portland cement), manufacturer sand, and river sand. Papercrete bricks can be easily shaped in any required form and are flexible and lightweight as the bricks are half the weight of a conventional clay brick, which leads to a decreased total dead load on the building and easier lifting to the desired heights. Delcasse et al. (2017) notes that it has good fire resistance and fly ash or coconut fibres can be added to improve Papercrete’s compressive strength. The only downside of Papercrete is that it can only be used for non-load-bearing walls and is not suitable for external walls or water logging.

2.4.3.4 Water saving sanitary ware

Water saving aerators and flow regulators can be used to decrease the amount of water when using the faucets of the wash hand basin, shower heads or the sink. Flow regulators can also be applied to urinals and duel flush systems can be used in conjunction with flow regulators to save water.

2.4.3.5 Light fittings and bulbs

Light fittings that have occupancy sensors can be used in passages and less commonly used areas with LED (Light Emitting Diode) types of bulbs as they are more energy efficient. More commonly used areas can make use of LED lights to achieve energy efficiency.

2.4.3.6 Energy efficient lifts

Nipkow & Schalcher (2006) stated that energy efficient lifts can be achieved by using energy efficient concepts and criteria for the professional team and public and reduce the stand-by consumption. Modern hydraulic lifts are also efficient in comparison to traction lifts due the counterweights being used and energy storage.

2.4.4 GBCs and Net Zero-Carbon Building Commitment

2.4.4.1 GBCs

Sedlacek and Maier (2012) stated that GBCs have formed in several countries over the years. The process to make the construction industry greener has become very important, organizations were established in various parts of the world to promote green building materials, as well as green and sustainable buildings. The WorldGBC is a non-governmental organisation that operates independently from the government. It is located in Toronto and has more than 75 organisations worldwide, one of which is the GBCSA located in Cape Town. GBCs have a wide variety of goals that they pursue, and their mission is to "facilitate the global transformation of the building industry towards sustainability through market-driven mechanisms" (Sedlacek & Maier, 2012).

The GBCSA works with community members to transform the built environment and have the planet prosper. The GBCSA (2017b) works in the residential, commercial, and public sectors to ensure that new and existing residential homes and buildings are designed, built, and operated in an environmentally sustainable manner. While the GBCSA commits to raising awareness, advocating, and implementing EDGE and GreenStar rating tools with successful infiltration in both the residential and commercial sectors, challenges faced by the GBCSA. The GBCSA launched campaigns to raise awareness among developers, businesses, financial institutions, and clients. While some developers implement green operations or build into their commercial properties, other sectors remain behind with the transition into green buildings (International Finance Corporation [IFC], 2016). However, it is not only GBCSA that has regulations to minimise the environmental impact of the construction industry.

The National Building Regulations and Standards Act (103 of 1977) and the South African National Standards (SANS) 10400-XA and SANS 204, published by the South African Bureau of Standards, encourage energy-efficient buildings and sustainable development and operation (Chemaly & Terreblanche, 2020).

Unfortunately, there is a demand for resource efficiency owing to the water and electricity crisis in SA. The IFC (2016) stated that R 300 million was provided by Business Partners Limited for green funding. South Africa's State-owned Industrial Development Corporation planned to invest USD 1.2 billion over the next five years into green developments. USD 10 million was invested by the Eskom Pension and Provident Fund (EPPF) and USD 30 million and the SA National Housing Finance Corporation (NHFC) to incentivise green development. The South African government announced the launch of a building energy-efficiency program led by the Department of Public Works and Infrastructure (DPWI). When developers or homeowners plan modifications to their buildings or build new developments, they need to meet energy efficiency standards. The IFC (2016) notes (Figure 2.8) that the most important social purpose for building green buildings is to encourage sustainable building practices. Second, to increase the productivity of workers, create a feeling of community and support the domestic economy. Third, it is used for aesthetic purposes.

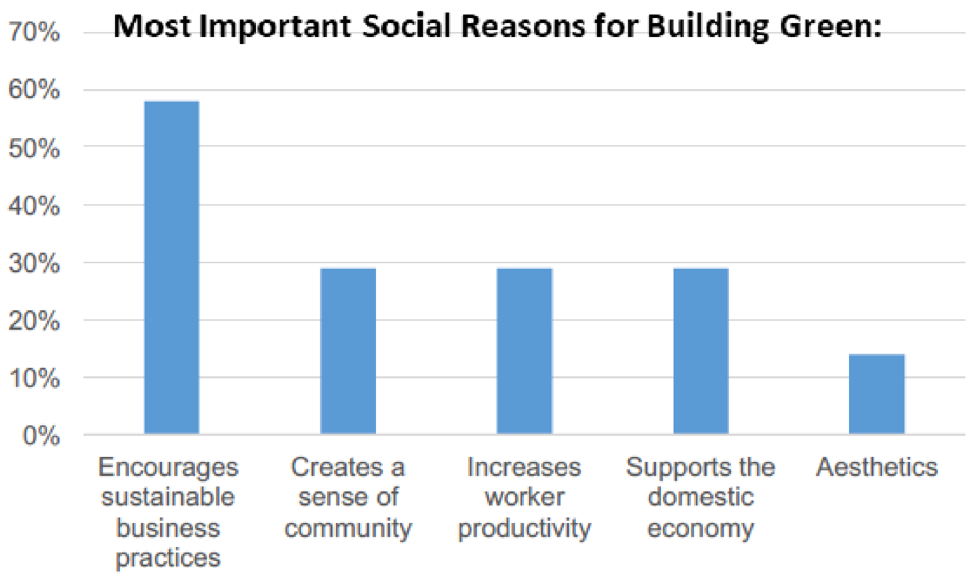

Figure 2.8: Social reasons to construct green buildings (International Finance Corporation, 2016)

The IFC (2016) adds that the top five triggers for developing green buildings are environmental regulations, market demands, client demands, healthier communities and because it is the 'right thing to do'.

Note that SA's top trigger of 40% is because it is the 'right thing to do', and their lowest triggers are for healthier neighbourhoods and environmental regulations, both with 23%. International respondents' top trigger is due to client demands (40%), and their lowest trigger is for healthier neighbourhoods (15%) (Figure 2.9).

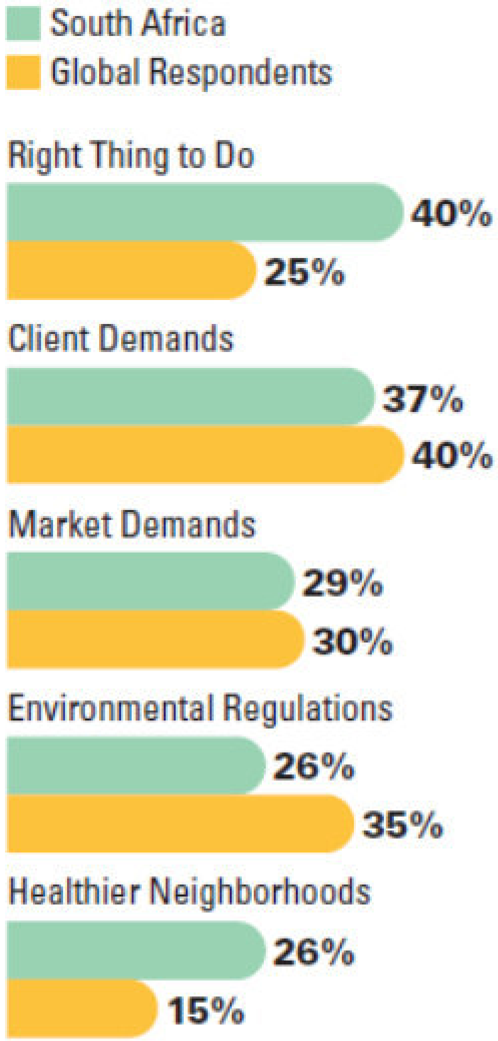

Figure 2.9: Top triggers for South Africa and international respondents to commit to green building (International Finance Corporation, 2016)

One developer that aims to be carbon neutral is Growthpoint, de Klerk (2023) (Growthpoint's CEO in SA) notes that green electricity and green developments are the solution to minimise the impact of human development, not only in SA but also in the world. Water shortages and electricity deficiencies are the main problems associated with SA. This means that green buildings and electricity are not currently a priority for the country.

Growthpoint aims to contribute to this by minimizing their carbon footprint in the country by using environmental, social and governance (ESG) performance. ESG performance and reports currently more commonly used by companies in South Africa and available to the public.

De Klerk (2023) states that their aim is to have all the buildings in their portfolio carbon neutral by 2050. The goal is to increase renewable energy use by five times by 2026 and reduce their GHG emissions by 25%. Growthpoint is converting their buildings to solar energy so that their tenants do not feel the impact of power outages.

As a leader in commercial green development, Growthpoint has around 71 green building certifications and has certified over 200 buildings since 2008. However, the sale of certain buildings and the ever-changing needs of clients, expiring certifications, and property management considerations mean that this number fluctuates annually.

2.4.4.2 How GBCs Assist with Embodied and Operating Energy

Dixit, Fernández-Solís, Lavy and Culp (2010) stated construction activities lead to emission of GHGs, environmental pollution, as well as energy consumption that causes climate change. Therefore, revisiting and altering manufacturing technology, construction techniques, and practices, such as engineering and design techniques, can flatten the energy consumption curve. Dixit et al. (2010) describes that a building’s total life cycle energy is made up of both operating energy and embodied energy. Embodied energy can be separated into building materials used throughout production, on-site construction, final demolition and disposal. Operating energy is consumed while preserving the internal environment of a building, which includes processes such as lighting, heating, and cooling of the building, as well as operating appliances.

Operating energy was previously believed to be the largest contributor to the total life-cycle energy (Dixit et al., 2010). Appliances and equipment are becoming increasingly energy efficient, and there are more effective and progressive insulation materials, resulting in a potential increase in the reduced operating energy. Therefore, the focus has shifted towards including the embodied energy of building materials. Furthermore, Dixit et al. (2010) elaborates that about 75% of the total energy set in buildings is owing to the off-site production of building elements, and this percentage is increasing because of energy intensive materials used. This creates a demand to measure the performance of both the operational and embodied energy of buildings in an attempt to minimise energy use.

Proper responsibility, on a large scale, for operating and embodied energy will create an energy economy of information and data for all direct and indirect contributions.

During the life cycle of a building, it requires energy to operate which Chemaly and Terreblanche (2020) defines as operational energy. Electrical and other services, results into increased energy usage. The cooling and heating inside buildings to obtain an ideal interior environment creates the need for energy in the building. Fortunately, technological improvements have improved the measurement of operational and embodied energy, making it easier.

There are different embodied energies in buildings, based on the specifications of each unique project and the area of the project. Chemaly and Terreblanche (2020) state that current technology, systems, building materials, and products influence the construction of a building the most. Embodied energy is created when the use and processing of raw materials and products for construction are used to build buildings. Chemaly and Terreblanche (2020) note that embodied energy is slightly more complicated than operational energy with regard to the calculation of emissions released. Therefore, further studies are warranted.

Building materials constructed using different technologies in the same geographical area at a similar time can reveal different energy consumptions (Dixit et al., 2010). Using various manufacturing technologies and the type of energy used may result in a substantial difference in embodied energy figures. Dixit et al. (2010) made it clear that the essential technological connection between the data source and their study is important to the LCA of a building.

2.4.4.3 Calculation of Embodied and Operating Energy

Chemaly and Terreblanche (2020) mention that there are three dissimilar courses of life cycle studies: Life Cycle Carbon Emissions Assessment (LCCO2A), LCA, and Life Cycle Energy Assessment (LCEA) (Figure 2.10). There are similarities between the methods used to assess the impact of construction on the life-cycle duration of a building and the environment. These methods are the most popular because of the reliability of results produced.

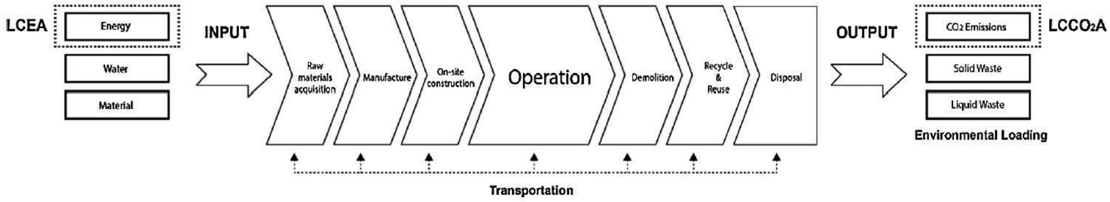

Figure 2.10: Basic ideas of LCA, LCEA and LCCO2A (Chau, et al., 2015)

The life cycle model has four main stages with a specific purpose, these stages are the Goal and Scope, Impact Assessment, Inventory Analysis and Interpretation. Phase one consisted of the Goal and Scope, where the boundaries, aims, and purposes of the assessment were emphasised. The second phase is Inventory Analysis, where all the associated data to the inputs are gathered. Phase three refers to the Impact Assessment, where the resource inputs are determined using an inventory analysis, and the environmental impact is calculated. The fourth phase refers to the interpretation phase, in which outcomes are evaluated and quantities are provided to enhance the system (Chemaly & Terreblanche, 2020).

The categories are pre-established for each study because the impacts of inventory used in the evaluation will be classified based on the type of effect it will have.

Chemaly and Terreblanche (2020) state that the LCEA is a simpler version of the LCA that can determine the embodied energy of building materials which can be used through the access of a database where environmental impact data are included. Embodied energy is created when the consumed energy is used in the production method, extending from raw materials excavated to the final product. Chau, Leung, and Ng (2015) are of the opinion that an LCEA analysis can be performed using primary or secondary energy, but it is important that the form of energy in focus be clearly stipulated to facilitate a comparison later. Primary energy is the energy removed from nature, such as coal (Chau et al., 2015). Secondary energy is energy which is consumed in reality, such as electricity.

LCCO2A considers the carbon emission output for the complete life cycle of the building. The environmental impact is determined by using carbon emissions over various phases of the life cycle of a building which includes fossil carbon emissions and emissions that occur during the manufacturing process (Chemaly and Terreblanche, 2020). In addition to the quantity of carbon emissions embedded in materials, buildings, and elements are the focus (Chau et al., 2015). Embodied carbon emissions are equal to the sum of carbon emissions from extraction and production, raw materials being transported, and product assembly. China was successful with LCCO2A, in which a model was created to calculate carbon emissions during the life cycle of buildings. In Sri Lanka, a study on multi-storey buildings indicated that the operation and management stage accounted for about 56% of carbon emissions of the life-cycle carbon emissions (Chemaly and Terreblanche, 2020).

The most important goal of whole-life carbon measurement (LCA, is to reduce the impact of carbon in the built environment) (RICS, 2017). To consistently measure and understand the whole-life carbon emissions of a commercial building will in turn allow benchmarks, results comparability, and goal setting to minimise carbon emissions. RICS (2017) states that assessments during the early stages of development are urged to establish a carbon estimate baseline for the project to integrate the whole-life carbon into the idea and design process, as well as to recognise the potential of minimising carbon emissions, while there is a chance to influence the decisions of developers, financers, and the professional team. This will, in turn, assist the professional team in understanding the whole-life carbon assessment impacts on the entire project and enable them to engage fully.
It will then be advisable for additional assessments at later stages of the project to monitor the carbon budget progress as the project develops and to provide an actual carbon footprint at the practical completion stage (RICS, 2017).

2.4.4.4 LCA Software

Bilec, Ries & Matthews (2010) stated that there are only a few studies on LCA, and office buildings published, but few of these studies include the on-site construction processes. Fortunately, different software can be used to model LCA for the production of carbon emissions (Chemaly and Terreblanche, 2020). The software uses its own database to create and determine the predicted outcomes of carbon emissions when constructing an office building.

RICS (2017) states that to determine what needs to be included in the whole-life carbon assessment for consistency purposes. It should consider all components of the commercial building, work related to the project, and external work within the boundary of the site. Furthermore, the site boundary must be in line with the intended purpose and definition of the commercial asset, as well as all adjoining land associated with the project and supporting its operations. A site boundary can be in the form of a town planning red line, where it might be available. Where there are communal or shared spaces, they must be allocated as suitable based on fair ratios derived from the respective floor areas of the adjoining properties, total occupants, or other capacity metrics for each commercial asset, including considering the intended use of the building (RICS, 2017). All items of the project’s Bills of Quantities, specifications, drawings, and other design information that fall under a certain type of building element should be covered by the whole-life carbon assessment, as noted by the RICS (2017).

Material passports can be considered as this is a digital document, as described by Buildings As Material Banks (BAMB) (2020), where building materials are listed that can be used, re-used from Material Banks in order to reduce wastage. It assists developers and the professional team see the value potential throughout the LCA of the building, as well as the capacity to follow the quality and modifications of building materials. Unfortunately, this is not yet adopted in South Africa, as it is currently adopted more Europe.

RICS (2017) is of the opinion that new commercial projects are believed to be constructed on flat, cleared sites for consistency purposes. Demolition works are often not associated with new development because the emissions from demolitions are not merely due to new development projects. Therefore, these emissions are reported separately. This is because of the possible opportunities for recovery, reuse, and recycling, as well as to enhance the demolition and deconstruction processes. Furthermore, the RICS (2017) notes that for projects that will be refurbished is represented by any preserved elements that are equivalent to a new built 'flat cleared site'. Building elements that are stripped out or removed to obtain the structure to a 'flat cleared site' must be treated as demolition works and reported separately.

All life cycle stages of a commercial project are considered by whole life thinking, from raw materials being extracted, manufacturing of products, transport, and installation on site to maintenance, operation, and material disposal. The potential for reuse, recovery and recycling is considered. RICS (2017) provides a modular approach to a commercial built asset's life cycle by breaking it into different stages (Figure 2.11).

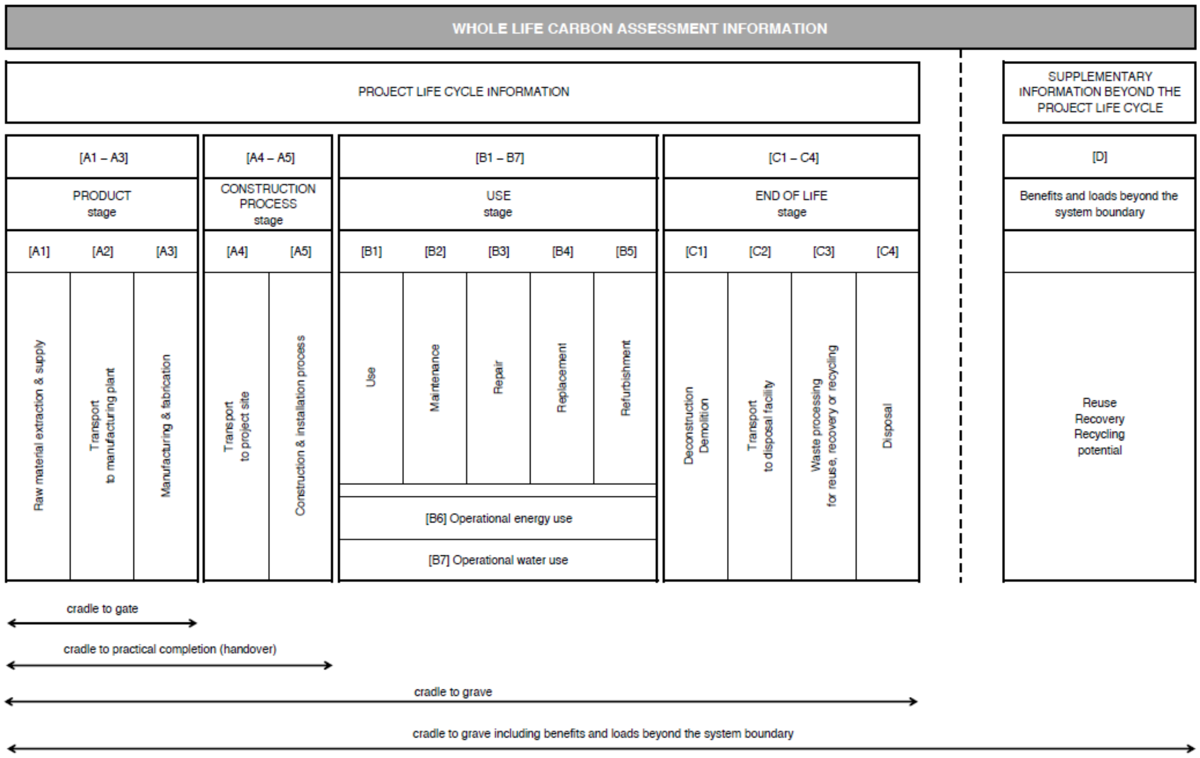

Figure 2.11: Whole-life carbon assessment information (Royal Institution of Chartered Surveyors (RICS), 2017)

All life-cycle stages of new commercial buildings are applicable. Existing commercial buildings that will be refurbished, all life cycle stages are applicable to any new elements installed in the building, items that will be preserved, and only emissions related to use [B], [C], and beyond [D] must be considered over the life cycle (RICS, 2017). All emissions produced from the construction stages and product [A] sit within the existing commercial building and are outside the scope of the project under study.

Current software has a few advantages and disadvantages, as well as limited access to software for the public. One advantage of software is that it can adjust variables to calculate the impact of a project on the environment (Chemaly & Terreblanche, 2020).

By inputting data into the software, it is possible to determine the effects on the environment based on the system's application of LCA methods. The application of software in the idea stage of construction will assist developers in making informed decisions to improve their building design and reduce embodied carbon (Chemaly & Terreblanche, 2020). The software currently available in the market is as follows.

SimaPro

It is a professional tool that gathers, analyses and examines a company's sustainability performance data. SimaPro can be used for carbon and water foot printing, reporting on sustainability, creating environmental product declarations, product design, and establishing key performance indicators (SimaPro, 2021). Based on SimaPro (2021), this software will assist in examining and modelling life cycles that are complicated in a systematic and transparent way, and will measure the impact on the environment of the company's product or service at each life cycle stage, as well as discover the hotspots in every link of the company's supply chain (from the raw materials being extracted, the production thereof, use, and disposal). When SimaPro is used, developers would require a licence for the software, which would range around USD 3,000.00.

EDGE

EDGE (2021) states that office buildings increase heat owing to computers, people, and near-constant lighting. The office building's location, the direction it faces, and how the building is used are some of the important factors that developers and clients need to keep in mind from the start. Typical mistakes by developers, architects, and clients make during the idea and design phase can be avoided if there is a well-engineered interior and an energy-saving façade (EDGE, 2021). The GBCSA is the forerunner that leads the transformation of the SA property industry to ensure that buildings are environmentally sustainable, designed, constructed, maintained, or operated. The GBCSA is an exclusive provider of EDGE certification in SA (IFC, 2016). EDGE Buildings are user-friendly and simple to use, and are suitable for the Green Building Rating online software platform, which is free to use and offers ways to reduce the resource intensity of a building.

EDGE accounts for the occupancy density, orientation of the building, and operational hours to model a base-case office building. Thus, designers can create a more effective and aesthetic workspace for minor, if any, additional costs. EDGE (2021) states that for developers that manage properties, green buildings can lead to higher tenant rental costs, and developers who sell green buildings can lead to about 7% higher asset value.

Furthermore, EDGE (2021) mentions that a green office building is an exceptional asset that stands out from the market, and that EDGE will aid office buildings to be differentiated in emerging markets. Based on the GBCSA (2017b), the EDGE standard was set to reduce categories by 20%, including water, energy consumption, and embodied energy. EDGE requires the building's utility costs, climate data, and building regulations to accurately determine the office building's inputs and outputs. For new buildings, basic project information and the application will identify how few practical water- and energy-saving options will improve the performance of the building at little or no cost (GBCSA, 2017b). EDGE will assist in determining green-building initiatives and financial viability at the idea stage.

It is important, as stated by the RICS (2017), to provide a credible estimate of the whole-life carbon emissions of a commercial project and consider any future decarbonation. This will allow stakeholders, developers, and financiers to consider the actual life cycle impacts of commercially built projects more broadly. It should be noted that non-decarbonised figures should be reported alongside decarbonised figures. RICS (2017) states that future decarbonisation must have a moderate methodology for calculating projected emissions. Necessary adjustments must be made to the carbon conversion factors to capture the decarbonization impact.

EDGE is currently supported by the UK, Switzerland, Austria, Canada, Denmark, Hungary, Finland, Japan, the Energy Sector Management Assistance Program, the Global Environment Facility, and the European Union (IFC, 2022). Based on EDGE (2022), green office buildings only require a rent ratio 3% higher than that of traditional office buildings. Green office buildings provide a higher return of 6.6% on investment and obtain a better occupancy ratio of 3.5%. This makes green office buildings attractive to the commercial market.

Using the EDGE application is simple because anyone can become a free user. A resource-economical building can then be designed to meet the EDGE standard using the following steps (IFC, 2022):

- The office building type must be selected in the application.
- The location data must be entered by selecting the country and city in which the project will commence.
- Enter the building data, stating whether it is an open-plan building, the gross building area, number of floors, operational hours, and occupation density.
- Enter the area details and office dimensions as accurately as possible to produce correct results.
- Enter the building orientation

- When the inputs on the Design tab are entered, the following step is to select methods to save energy.

Figure 2.12: EDGE application can be used on any device.

IFC (2022) states that resource-efficient development or retrofitting can be designed in less than 30 minutes with EDGE. EDGE can be used to establish solutions at a low cost that makes the most sense when considering the client's preferences. The application has built-in climate data which is specific to where the development or existing office building is located to ensure the most precise results. Furthermore, the IFC (2022) notes that the EDGE application can be used on any device (Figure 2.12), which means that a Quantity Surveyor (QS) can sit in a meeting with the client, fill in the data, and obtain methods to save energy in the building and look at methods that will not have a significant financial impact on the client. The QS will be able to advise on which method will be better suited for the client in the early development stage, or if the client would prefer to pay the monthly carbon tax.

EDGE has an archive of Project Studies listed of all EDGE-certified projects that obtained Preliminary EDGE certification or Final EDGE certification. Fifty office developments, including both newly constructed and retrofitted buildings, have been identified and chosen based on climate conditions similar to those of South Africa.

Each development demonstrates the typical optimal energy, water, and material solutions utilized to achieve EDGE certification and reduce carbon emissions. A summary of these office developments can be found in Annexure E: EDGE Certified Projects.

2.5 Carbon Tax

2.5.1 Defining Carbon Tax

SA is not alone in its attempt to implement carbon taxes and fight climate change. Duncan (2019) states, 46 national and 24 subnational jurisdictions enforced carbon tax by November 2018. WWF South Africa (2019) stated that a carbon tax is a method by the government to put a price on the emissions of carbon and to place the cost on emitting companies, rather than on society. Thus, more taxes must be paid when a company emits more emissions. Climate change has an impact on the prices of food, water, infrastructure, health, conflicts, and disasters. Where the public is already paying for these costs, this tax helps shift it to real wrongdoers. When a company contributes to reducing emissions or becoming a low-carbon emitter, the less tax it will pay. As defined in Section 3 of the Act (Carbon Tax Act 2019), persons who are subjected to tax are taxpayers for purposes that are set out in the Carbon Tax Act and who are legally responsible for paying a carbon tax amount which is calculated. When a person conducts activities in their business activities, this results in GHG emissions that exceed the threshold expressed in the Act under Schedule 2.

The South African Revenue Services (SARS) (2020) states that Carbon Tax is designed and enforced on persons or entities “that operate emissions generation facilities at a combined installed capacity”, this capacity either exceeds or is equal to the threshold of carbon tax. The cost related to climate change impacts will be far more than the cost implication of reducing emissions through methods such as carbon tax. WWF South Africa (2019) provides an example that the impacts of the rainfall and crop disease patterns that are changing, extreme storms, droughts, and increasing temperatures are driving a change in agriculture which leads to an increase in food prices.

Duncan (2019) stated that there was a debate from 2010 concerning the net effect carbon pricing will have in the SA economy which was quite controversial for concerns that ranged from financial impact and international competitiveness to labour and local industry concerns. Although the impact of carbon tax might be minimal currently, it is an additional expenditure that needs to be incurred by the public and puts a strain on their income.

In addition, Oxford (2019) added that there was an outcry of shouts and concerns that the Carbon Tax was unconstitutional. One of the concerns was that the SA treasury would not ringfence the funds received in the form of Carbon Tax and re-invest it into carbon reduction technologies.

The treasury refuses to ringfence this tax because of the allocation of funds and governance, as the amount of carbon that is polluted must, in principle, be used to decrease the same amount of carbon emissions. Unfortunately, Oxford (2019) states that this is not the case because there is a complicated structure for carbon taxes, adding to more administration, expenses, and complexity.

Sometimes, society tends to think that taxes are a way to increase the tax base. However, the purpose of this tax is to make consumers aware of the impact of climate change and carbon emissions (Legg, 2019). Making consumers aware of this problem will contribute to changing their emitting behaviours, and it will stimulate the investor appetite to shift it towards changing to low-carbon buildings. However, the government must commit to implementing revenue recycling measures. Oxford (2019) stated that this tax would be beneficial to South Africa's dynamics and would put the country on a stronger foot when it comes to international perceptions.

SARS (2020) describes the carbon tax as a new tax which is put into place in SA in response to climate change, aiming to provide an affordable, cost-effective, and sustainable manner in which GHG emissions can be reduced. Carbon taxes motivate consumers and companies to consider the negative adverse costs of climate change when they make decisions regarding consumption, production, and investment. Furthermore, SARS (2020) explains that carbon tax give effect to the "polluter-pays-principle". GBCSA (2019) wrote the following:

> The implementation of the Carbon Tax Bill in June can be seen as a significant achievement for the green building sector, and indeed every sector in South Africa working towards sustainability and carbon neutrality.

On 19 February 2019 the controversial Carbon Tax Bill was passed in the SA parliament after a decade-long consultation and debate process, which was formally announced during the National Budget speech the next day. The Carbon Tax Act of 2019 came into effect on the 1st of June 2019 and was collected and administered by SARS (2020).

GBCSA (2019) stated that it was first debated in 2010 along with the Carbon Tax Discussion Study, followed by the Carbon Tax Policy Study in 2013, The Carbon Offsets Study in 2014 and then the original Carbon Tax Bill in 2015. Civil society, companies, labour, non-government organisations, government line departments, and state-owned entities have submitted their comments. However, resistance came with no surprise from the parties who represented heavy emitters.

Duncan (2019) stated that this announcement by Government of a market-based carbon pricing mechanism is an essential step to start a low-carbon growth path to target the companies which are more energy- and carbon-intensive.

ESI Africa (2019) noted that sectors that will experience the current impact will be those that have an installed thermal capacity of 10 MW or more and need to report their carbon emissions immediately. The shopping centre’s load may vary from 3 MW to 5 MW, industrial warehouses can be more or less 10 MW, and mining operations normally reach 600 MW. ESI Africa (2019) stated that all sectors will be liable for carbon tax, except the Agriculture Forestry and Other Land Use and waste sectors which will be exempted for the first phase of implementation of carbon tax due to the difficulties of measurement.

The Carbon Tax Act of South Africa states that ZAR 120 per 1 000 kg of carbon tax will be charged for primary GHG emitters which will be implemented in a two-phase approach (Duncan, 2019). GBCSA (2019) states that any person (whether it is a trust, community, partnership, public listed entity, or municipal entity) that conducts activities which cause their GHG emissions to be above the allowed threshold will be responsible for paying the initial phase of carbon tax.

This first phase will be implemented between June 2019 and December 2022 to help companies ease their transition by becoming either carbon tax compliant or changing their emission methods and renovating their buildings to net zero-carbon buildings. Duncan (2019) states that the tax will increase by 2% at a rate of inflation above the consumer price index, as determined by Statistics South Africa (Stats SA, 2023), and is an addition to corporate tax. However, the Climate Action Tracker (2020b) stated that the instant impact of the implementation of the Carbon Tax will be constrained because the first payment of this tax was delayed by three months due to COVID-19. Duncan (2019) mentions that there are tax exemptions and rebates available which might lead to emitters paying only between ZAR 6 and ZAR 48 per 1 000 kg of carbon emitted, which might defeat the purpose of achieving a high rate of awareness one wants to create as soon as possible.

SARS (2020) explains that there are considerable allowances for industry-specific tax-free emissions that range from 60% to 95%, and it will have a tax rate that ranges from R6 to R 48 to ensure that current emitting persons or companies can transition their operations to technologies that are cleaner by making use of renewable and energy-efficient investments, as well as alternative low-carbon measures. The Carbon Tax Act (2019) states that a taxpayer may not receive a tax exemption exceeding 95%. Schedule 2 of the Act sets out thresholds concerning electricity use by building occupants, whether it is a company or tenant for commercial or residential electricity and heat use. Table 2.1 indicates that the thresholds for both residential and commercial operation activities are 10 MW (th) installed input capacity for combustion activities, resulting in emissions.

Swart (2019) indicated that if a building has the capacity to combust more than 10 MW (th), regardless of the use or fuel type, then the emissions will be subject to carbon tax. The maximum total tax-free allowance for commercial operation activities is 90% and that for residential operation activities is 100%.

Table 2.1: Schedule 2 – Carbon Tax Threshold for residential and commercial sectors (extracted from Carbon Tax Act 2019)

IPCC Code	Activity/Sector	Threshold	Basic tax-free allowance for fossil fuel combustion emissions %	Basic tax-free allowance for process emissions %	Fugitive emissions allowance %	Trade exposure allowance %	Performance allowance %	Carbon budget allowance %	Offsets allowance %	Maximum total allowances %
1A4a	Commercial/Institutional	10 MW(th)	60	0	0	10	5	5	10	90
1A4b	Residential	10 MW(th)	100	0	0	0	0	0	0	100

Table 2.2 indicates that the threshold for manufacturing industries and construction is 10 MW (th) installed input capacity for combustion activities, resulting in emissions subject to carbon tax. The maximum total tax-free allowance for both the manufacturing and construction industries was 90%.

Table 2.2: Schedule 2 – Carbon Tax Threshold for manufacturing industries and construction sector (extracted from Carbon Tax Act 2019)

1A2	**Manufacturing Industries and Construction (including heat and electricity recovery from Waste)**		60	0	0	10	5	5	10	90
1A2a	Iron and Steel	10 MW(th)	60	0	0	10	5	5	10	90
1A2b	Non-Ferrous Metals	10 MW(th)	60	0	0	10	5	5	10	90
1A2c	Chemicals	10 MW(th)	60	0	0	10	5	5	10	90
1A2d	Pulp, Paper and Print	10 MW(th)	60	0	0	10	5	5	10	90
1A2e	Food Processing, Beverages and Tobacco	10 MW(th)	60	0	0	10	5	5	10	90
1A2f	Non-Metallic Minerals	10 MW(th)	60	0	0	10	5	5	10	90
1A2g	Transport Equipment	10 MW(th)	60	0	0	10	5	5	10	90
1A2h	Machinery	10 MW(th)	60	0	0	10	5	5	10	90
1A2i	Mining and Quarrying	10 MW(th)	60	0	0	10	5	5	10	90
1A2j	Wood and Wood Products	10 MW(th)	60	0	0	10	5	5	10	90
1A2k	Construction	10 MW(th)	60	0	0	10	5	5	10	90
1A2l	Textile and Leather	10 MW(th)	60	0	0	10	5	5	10	90
1A2m	Brick manufacturing:	4 million bricks a month	60	0	0	10	5	5	10	90

The second phase will only be implemented at the beginning of 2023 with a higher tax rate, which will start to align with the global rates and impact large-emitting companies (Duncan, 2019). GBCSA (2019) mentions that up to ZAR 600 tax per 1 000 kg of carbon emitted may be charged to emitting companies. The tax will be enforced, assessed, and collected as an environmental levy, the Customs and Excise Act of 1964, and will be read with the applicable provisions of the 2019 Carbon Tax Act (SARS, 2020). However, Oxford (2019) raised the concern that there might be several complexities for a company which chooses to be a complaint as there are numerous boxes to be checked, including identifying the emission source and determining the control over the activity which may be more a pointless administrative exercise.

Legg (2019) describes that the Bill, along with supporting documentation, sets out the technical workings of the tax and when companies or persons are not familiar with the carbon emissions or the calculation thereof, a carbon services consultant will help them navigate through the process. It is important for all persons and companies involved to assess whether they will be exposed and liable to this tax, as well as the extent to which they are exposed to start and plan to transition away from relying on carbon.

Oxford (2019) notes that a Carbon Tax is a vital step in SA's commitment to meet the goals of the Paris Agreement and reduce its GHG emissions. Companies and investors should focus on the carrot rather than the stick, to recognise the advantages of zero-carbon buildings, such as using solar power.

Developers, companies and tenants will be driven by costs that produce GHG like fossil-fuel generated electricity and waste disposal. Oxford (2019) adds that replacing the building's energy mix with energy solutions, such as a solar PV system, will be a cost-effective method to reduce the building's carbon emissions and operation costs. There are tax incentives to go green, where developers and tenants can claim deductions under Section 12 L of the Income Tax Act of 95c per kilowatt-hour of energy efficiency savings made in a year against a verified twelve-month baseline. Oxford (2019) states that Section 12B has a provision for an accelerated wear-and-tear allowance for movable assets used in renewable energy production which could provide up to a 28% reduction in income tax in the year in which the asset is brought into use. The advantages of these tax deductions make using battery and rooftop solar systems feasible for tenants, companies, and developers.

Duncan (2019) states that it is no surprise that the financial ecosystem is seeking out ways to reduce the risks in market while simultaneously taking advantage of the emerging opportunity set. Currently, capital flows into the renewable energy infrastructure which is supported in the green bond market and is growing over time. Duncan (2019) mentions that the consequences of an additional tax cannot be ignored (like the potential of poverty, unemployment, and inequality), but climate change might add to this problem by this triple threat within the SA context which needs to be addressed urgently.

Long-term investors are given a new variety of opportunities when it comes to a low-carbon economy transition, which includes areas such as energy efficiency, renewable energy, green properties, green bonds, and energy charging/storage. The intent of the national budget is to be revenue-neutral, and the first phase is a combination of revenue-recycling and tax incentives to manage the impact on the economy (Duncan, 2019). Carbon Tax is an essential step for South Africa and its economy to grow into a low carbon economy with the aim to improve energy efficiency, encourage cleaner alternatives and technologies, as well as discourage carbon-intensive investments in the future.

The National Climate Change Response Policy of 2011 facilitated the transition to a reduced carbon climate resilient economy by providing an overarching policy framework (National Treasury, 2018).

This policy provides for using disincentives and incentives, which include economic, regulatory, and financial measures, to provide proper price signals to guide the economy towards a path of sustainable growth. Based on the National Treasury (2018), the “Polluter Pays Principle” will be used to develop appropriate measures. Companies and persons responsible for harming the environment will pay the appropriate costs to improve the pollution and degradation of the environment as well as support any resulting adaptive response that may be necessary. Therefore, a carbon tax framework and policy have been developed for using carbon offsets alongside the polluter pays principle.

The Carbon Tax Bill provides such that a carbon tax will be introduced in phases. In SA, the steady approach takes cognizance of the developmental challenges that this country may face, and the nationally determined contribution (NDC) commitments made toward the Paris Agreement. Gootkin (2023) states that the Carbon Tax Act of 2019 is South Africa’s government approach to minimize the GHG emissions by motivating companies to invest in cleaner technology and focus on alternatives that reduce these emissions. This is a way to encourage the transition to a low-carbon SA economy. This tax is applicable to a variety of sources that cause emissions, including fossil fuel combustion, electricity generation, and fugitive emissions created by industrial processes and mining.

Carbon credit was introduced to limit the amount of GHG emissions produced (Gootkin, 2023). Local companies have incorporated ESG reporting to reduce the impact of their operations on the environment by investing in carbon credits from projects that have reduced GHG emissions or in their own projects. However, it is not a voluntary market, as currently, only large developing companies with international ties are committed to reducing their GHG emissions. The carbon offset administration system (COAS) was introduced, in which carbon taxpayers can transfer carbon credits to reduce their carbon tax liability. COAS is a ledger where credits are sold or bought for use. Gootkin (2023) adds that the implementation is the problem currently, although the policy is designed effectively. Unfortunately, the country is delaying its efforts to decarbonise, as there remains a dependence on coal and a lack of awareness among developers.

2.5.2 Implementing Carbon Tax

2.5.2.1 Tax Base

Environmental challenges, including water pollution and climate change, occur when the assimilative capacity is surpassed by a certain environmental resource.

The National Treasury (2018) states that the community is affected by subsequent extreme pollution, but the polluter sometimes does not pay the cost for pollution. Negative externalities are due to market failures where pollution costs are not displayed in the final services and goods. Governments will address market failures by putting regulations and/or market-based instruments into place (e.g. emission trading schemes or taxes) to affect the manufacturing, investment, and expenditure decision-making processes of manufacturers and customers. The two methods used to price carbon emissions are as follows: (1) carbon tax and (2) emission trading scheme or cap-and-trade mechanism.

Both approaches have been used by various jurisdictions on carbon pricing which cover different sectors. There is a limit on emissions, as prescribed by regulations, where companies need to obey that limit, or they will need to pay significant penalties. The costs associated with these limits are identified as an indirect form of carbon pricing. Unfortunately, this may not always be the most cost-effective method for minimising GHG emissions (National Treasury, 2018).

Based on the National Treasury (2018), an emissions trading system (ETS) for South Africa is not fitting because GHG emissions are only dominated by a small number of companies.

The ETS is quite complicated and involves substantial building capacity efforts and an established infrastructure. Under these circumstances, it is not likely to create a strong market that will lead to reliable carbon prices but may result in a very unpredictable carbon price. Therefore, the carbon tax will deliver the required policy confidence and price signals to drive behaviour change in the short, medium, and long terms, and the carbon tax is easily governed. Furthermore, the National Treasury (2018) adds that when a carbon offset mechanism is included in the carbon tax design, it will serve as a market mechanism and provide flexibility for businesses to minimise their carbon responsibilities while participating in GHG emission reduction projects. Later on, it may be likely to connect with the international trading scheme in the medium to long term.

The carbon tax design is informed by the administrative practicability and feasibility of including most GHG emissions. The necessity to shift to a low-carbon economy in a sustainable manner, over a long period of time and as smoothly as possible, is considered. The phased-in approach and high-level tax-free allowances guarantee that SA’s competitiveness is not compromised. The National Treasury (2018) added that actions have been taken to safeguard vulnerable homes and communities against carbon tax.

To reduce the effect of the first phase of the policy, the application of a carbon tax will be accompanied by a package of revenue recycling measures and tax incentives until 2022 (National Treasury, 2018). The first phase of the carbon tax will not influence the electricity price to control the possible adverse impacts on energy-intensive sectors (e.g. the steel, iron, and mining sectors).

Tax credit can be obtained when there is a renewable energy premium built into electricity rates as well as credit for existing electricity generation tariffs. Free basic electricity and/or alternative sources of energy allocation are prioritised and improved. Tax is based on the input of fossil fuels (e.g. oil, gas, and coal) and using accepted methods. The authorised procedures and emission factors can be used to measure carbon dioxide equivalent (CO2-eq) emissions fairly accurately for various sectors and methods. The National Treasury (2018) states that reporting of emissions will be based on compulsory reporting requirements for GHG emissions which are approved by the National Inventory Unit within the Department of Environmental Affairs and Tourism (DEAT), as per the 2006 Intergovernmental Panel on Climate Change default emission factors.

Mandatory reporting thresholds provided in the National Greenhouse Gas Emission Reporting Regulations are based primarily on GHG emissions, energy production, and consumption.

Entities that have a total installed capacity for an activity equal to or above the specified threshold, which is mainly 10 MW total installed capacity, must report their emissions and will be subject to tax in the first phase of the carbon tax (National Treasury, 2018).

2.5.2.2 Tax-Free Allowances

Several tax-free allowances are made available to transition efficiently into a low-carbon economy based on extensive stakeholder engagements (National Treasury, 2018), including the following:

- Sixty per cent basic tax-free allowance;
- Ten per cent additional tax-free allowance for fugitive emissions;
- Ten per cent additional tax-free allowance for process emissions;
- Five per cent maximum tax-free allowance for above-average performance;
- Ten per cent maximum variable tax-free allowance for trade-exposed sectors;
- Five per cent tax-free allowance when a business has a Carbon Budget;
- Five or 10% carbon offset allowance; and

- During the first phase of the carbon tax, the total tax fee allowance reached a maximum of 95%.

The National Treasury (2018) states that after a minimum of three years, the carbon tax impact will be reviewed, and adjustments will be made to the design of the carbon tax (which includes the level and rates of tax-free thresholds) by considering the progress made to reduce GHG emissions and the economic circumstances in SA. The revision of the carbon tax will be subject to a similar consultative and clear process, as previously done for all tax legislation after the budget announcements made by the Minister of Finance.

2.5.2.3 Carbon Tax Rate and Liability

The carbon tax will be ZAR 120 per 1 000 kg of carbon emissions, above the tax-free threshold. However, because of tax-free allowances, the carbon tax rate may decline to between ZAR 6 and ZAR 48 per 1 000 kg of carbon emissions emitted. Section 5 of the Carbon Tax Bill indicates that there will be an increase in the tax rate per year by the rate of consumer price inflation plus 2% until 31 December 2022 and that the adjustments will be in accordance with inflation from 2023 (National Treasury, 2018). Currently, owing to the COVID-19 pandemic, the increase might be put on hold while the economy recovers.

Certainty will be brought to companies, and the long-term price signal will be clear, in line with the Carbon Tax Policy Study of 2013.
As The National Treasury (2018) states that the Carbon Tax Policy Study of 2013 “proposed that the tax rate of a R120 per tCO2-eq be increased at a rate of 10 percent per annum until the end of 2019, followed by a review during 2019, with the intension to announce a revised annual rate of increase in the 2020 budget”.

Carbon Tax can be calculated as follows:

Tax base = Total quantity of GHG emissions from fugitive, combustion, and industrial processes minus tax-free allowances.

Carbon tax = tax base x rate of carbon tax

2.5.2.4 Administration of Carbon Tax

An accurate system is needed for observing, reporting, and confirming emissions for tax implementation. The National Treasury (2018) mentioned that SARS will be the main body implementing administrative power on the liability of tax calculation and will have access to the DEA emissions database. DEA will assist SARS in confirming the emissions reported to audit companies' self-reported tax responsibility. Companies are permitted to use their DEA registration information for the SARS process because the taxable entity registered with SARS is aligned with the reporting entity which is registered with the DEA. The DEA will lead the monitoring, reporting, and verification process, where GHG emissions collected data will form part of the tax base.

2.6 Managing Carbon Emissions through Carbon Tax or Energy Efficient Buildings

2.6.1 Sri Lanka

Commercial property owners / developers of Sri Lanka adopted green leases as part of their rental agreements with their tenants with the goal set to conserve water and energy, recycle and minimize waste, as well as using non-toxic cleaning products, (Green Building Alliance, 2024).

B.A.K.S. Perera & Mallawaarachchi (2017) noted that green leasing ensures to provide a comfortable environment for tenants in combination with higher profits for the commercial property owners / developers. Green leasing is therefore required to ensure that a green building is efficient. However, majority of the public are still unaware of green leasing, there is little commitment from the government and less financial incentives that can assist with the green development and green leasing.

2.6.2 Africa

Africa remains in the early stages of adopting energy-saving and environmentally sustainable methods (Sayigh, 2014). The construction sector has enhanced a few measures over the last few years, but it must be further developed by implementing a new model for economic growth based on sustainable ecological development. The need to construct buildings, develop communities, and create job opportunities must be balanced by going green (Weidemann, 2023), but this may be difficult to find a balance. The construction industry needs to be aware of a few sustainable development problems.

Sayigh (2014) provides a few guidelines that developers can follow to develop sustainable buildings and avoid incurring additional expenses through a carbon tax. Because of the difference in the climates in Africa, several strategies can be applied to create a balance between the climate and the building; e.g., passive or bioclimatic design strategies. Passive design strategies seek to reduce building energy consumption and provide a comfortable environment inside the building. Buildings can then adapt to the external environment by means of clever use of building materials and elements, architectural design, and avoiding using mechanical systems which use fossil fuel energy (Sayigh, 2014). Fossil fuels generate electricity which contributes to global warming. Passive procedures can reduce the energy consumption in commercial buildings. The primary aspects of a building are the orientation, shape, and selection of the building site for a new commercial project, and for existing buildings, the shape and building orientation (Sayigh, 2014). Optimal exposure must be considered for general winds and sun paths for effective ventilation and to improve indoor comfort.

Green Building Consulting & Engineering (2023) states that purchased energy is made use of for Active design strategies, because these systems are powered. Technologies of Active design include converting energy into electricity using wind turbines or heat harvesting systems and solar panels.

Tobias (2005) notes that the building envelope or shell comprises all the building components between the external environment and the internal space of the building. Envelope influences the internal comfort conditions of a building by maintaining sound, moisture, light, and temperature. Therefore, the maximum potential for the overall building performance was identified. Tobias (2005) notes that the roof insultation in a new or existing commercial building can be modified to have an additional insulation layer being installed beneath the exterior layers of the roof or foam and friction-fit (batt) can be mounted to the underside of the roof or at the surface of the thermal envelope. A radiant barrier can be installed to deflect unwanted heat radiating from the building.

The external walls of a commercial building can be modified or designed to have rigid board insulation attached to the external wall and then covered with either stucco or metal siding panels to serve as a protective barrier (Tobias, 2005). This will improve energy performance and provide aesthetic qualities to commercial buildings. In existing buildings, insulation can be inserted into internal cavity walls that require wall insulation. Sayigh (2014) adds that the light colours of external walls and other coating materials will reflect a significant amount of solar radiation; e.g., white paint.

The temperature of the building envelope is minimised when light-coloured coatings are applied, as well as when heat is conducted into the commercial building. Energy is absorbed by dark materials, where more energy is reflected through light colours. Sayigh (2014) added that sealing the walls will prevent the penetration of hot air and reduce surface condensation problems that may arise.

Sayigh (2014) stated that the arrangement and configuration of the internal layout of a commercial building contribute to exposure to solar radiation, ventilation, and natural lighting. Therefore, it is important that the size of openings is sufficient for natural lighting and ventilation. Shading assists in minimising the solar heat radiating into the building and offers protection to the opaque envelope and areas of windows (Sayigh, 2014). Because windows do not have sufficient resistance to transfer radiant heat, the heat gained through them can be substantial. Sayigh (2014) notes that providing shade to glazing areas will protect the internal space from solar gains on windows positioned to the west and east because the angle of the sun is low in early mornings and late afternoons. Shading can be in the form of admitting light, internal or external, and adjustable or fixed (Figure 2.13).

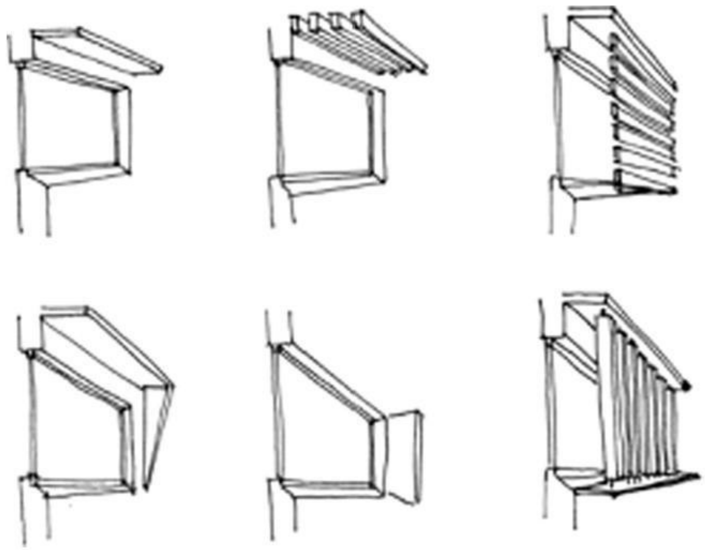

Figure 2.13: External shading examples that can be considered (Sayigh, 2014).

Sayigh (2014) states that windows transfer radiant heat owing to low resistance by glazing. The type of glass, sizing, and orientation of glazed areas are influenced by the filtration of solar radiation into the building. No more than 30% of the glazing area must be allowed in the southerly and northerly façade areas because these windows are believed to have sufficient shading. The value must be 20% for windows in the easterly façade, and western façade windows must be avoided, where possible. Double-glazing can be incorporated to influence the heat loss or gain (Sayigh, 2014).

The type of glass can be changed to transmit only the parts that are visible to the solar spectrum needed to reflect radiation and natural light (low-emissivity glazing). The window opening size and insulation of the non-transparent building envelope can prevent heat gain entry through either the walls or glazing areas.

Sayigh (2014) explains that the airflow that travels between the inside and outside of a building is known as natural ventilation. The two natural elements can cause natural ventilation by means of wind-driven ventilation or wind around the building, creating pressure and temperature differences. Openings must be designed to improve airflow distribution throughout the building. Obstacles such as internal walls or partitions can hinder natural ventilation. Therefore, entrance and exit openings should be carefully planned. Vertical windows of shopfronts create a better arrangement of internal space and natural lighting as well as provide a high standard of ventilation (Figure 2.14).

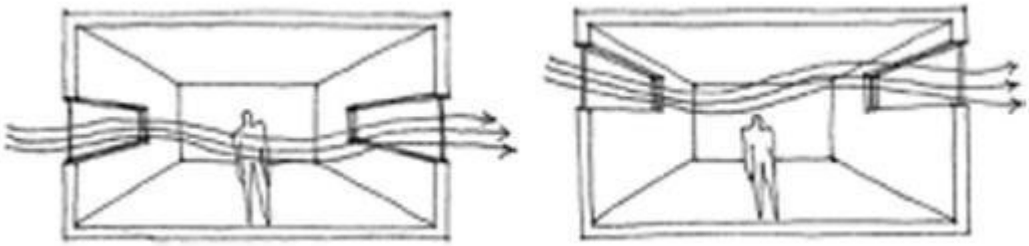

Figure 2.14: Potential positioning of windows in the facade for natural ventilation (Sayigh, 2014)

Sayigh (2014) suggests that a thermal mass can provide comfortable indoor conditions, as it acts as cold or heat storage that smooths and regulates temperature fluctuations. Heat stored throughout the day can be dispersed at night through night ventilation. Dormancy slows the exchange of heat by conduction to the exterior. Thermal mass should preferably be used in conjunction with other ventilation strategies. Lastly, Sayigh (2014) noted that an opening at the top level, or a ventilated roof, can assist in removing hot air from the building (Figure 2.15).

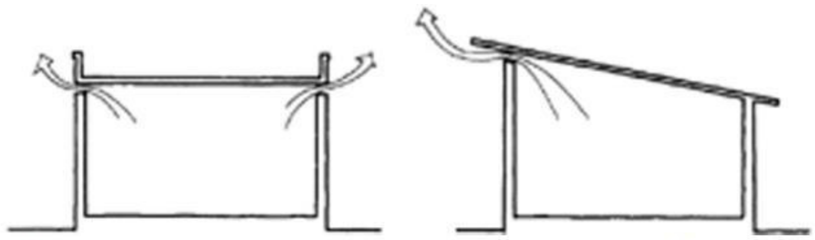

FIGURE 16.98 In the case of pitched roofs, the opening should be in the higher wall.

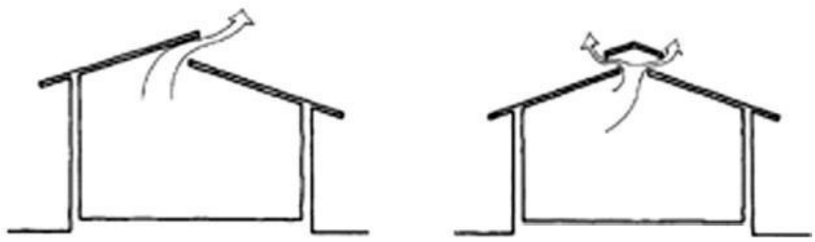

FIGURE 16.99 Two resources to force air movement through the opening in the ceilings.

Figure 2.15: Different types of ventilated roofs, (Sayigh, 2014)

Tobias (2005) states that there are two other roof alternatives that can be incorporated into the buildings, namely building-integrated photovoltaics (BIPVs) roofs and vegetated roofs. BIPVs are materials in the building envelope that replace the standard material used and can be used on sloped or flat roofs. BIPV generates electricity in the form of renewable energy and performs the role of a standard roof. In vegetated roofs, a layer of plants is planted on a waterproofed roof. Vegetated roofs contribute to the mitigation of energy as they have insulating qualities, are good for sound reduction, manage stormwater runoff, and increase the useful life of the roof. Plants promote the reduction of temperatures in buildings by way of evapotranspiration (Tobias, 2005). Vegetated roofs are a feature of commercial tenants aiming for sustainable operations; the building becomes aesthetically pleasing and lessens the urban heat island effect.

2.6.2.1 South Africa’s Transition to Zero-Carbon Buildings

The National Business Initiative (NBI) (2022) is of the opinion that the cost when South Africa does not act towards climate change will be significant, because the world is moving towards decarbonisation, where trade partners will act on their commitments if net zero. Thus, SA should not act, 50% of SA’s export value, 15% of its gross domestic product (GDP), and about 1 million jobs would be affected negatively. Worsening conditions in the country of poverty, inequality, and unemployment. It is important that SA steps up to the challenges and transitions to a low-carbon competitive and climate-resilient economy while addressing the challenges of unemployment, inequality, and poverty.

The NBI (2022) states that SA can achieve its commitments to reach net zero by 2050 and 350–420 $MtCO_2e$ of the NDC, but change comes with a few unknowns and resistance, and public awareness in SA with regard to net zero buildings and carbon tax on these buildings is extremely low.

Commitments can be achieved when SA acts as follows NBI (2022):

- The deployment of renewable energy is 10 times higher than that currently deployed at 6-7 Gigawatts per year to increase the gain of green H_2 opportunities;
- Ensure that coal power is phased out by 2040;
- Selling more than 700,000.00 electric vehicles to ensure electrification in transport by 2023;
- Decrease the number of conventional vehicles on the road and prohibit their use by 2035; and
- Increase using rail transport by 15% to 20%.

NBI (2022) advised that it is essential for renewable energy to be the primary energy carrier with less dependence on fossil fuels. In addition, communities need to change their behaviour to use more public transport, reduce their red meat intake, and maintain a sustainable diet, including living in sustainable and smaller houses. Sadly, if all of these actions are taken, SA might not meet its international commitments by 2030, as NBI (2022) states that the predicted emission reduction will be 409 $MtCO_2e$ which is only a 20% reduction from 2017. This is due to the country's standstill during 2020, when there was an inadequate emission decrease. SA must take a disruptive decarbonisation action, which includes the actions listed above, across all sectors to meet the requirements of the 2030 NDC. SA have a wide range of needs, and more energy is required to supply the community with electricity and ensure economic growth by reducing poverty (Sharpe, 2023).

Therefore, international support is needed to support these actions, as the community has limited capacity and socio-economic risks are involved. These risks include people not being able to afford greener technologies due to high prices, and low income in the coal community due to lower coal use. SA needs financial, technological, and trade support as well as capacity and skill development. Job creation is required to guarantee that this transition is fair.

Sharpe (2023) believes that South Africa requires ZAR 250 billion to invest in infrastructure for this transition, but the question is whether investors are comfortable investing in projects in this country.

Political differences cause delays in the decarbonation process which may make investors hesitant to invest. Furthermore, Sharpe (2023) noted:

> "if you look at the politics around environmentalism, you have people saying climate change was largely caused by developed nations polluting, so why should we now pay the price by not using the resources that we have in abundance? It only requires a change in ANC leadership for shale gas reserves to be exploited. The unpredictability within the ANC presents a risk for investors".

An economy that remains carbon intensive is destined to become less competitive, South Africa will be less competitive internationally when it still relies on fossil fuels to produce electricity. There will be a great shift in this country when capital can be invested in renewable off-grid energy. Currently, it is not mandatory for the private sector to transition to zero-carbon, including the need to transfer skills and create marginalised communities relying on the coal value chain. Mpumalanga is the province with the highest risk. One person working in the coal industry supports 10 people (Sharpe, 2023). The private sector needs to be more proactive in their transition which will in turn increase opportunities for investment, but a few challenges need to be overcome, such as political instability, the debt-to-GDP ratio, being grey-listed, and the downgrading of the credit rating. Therefore, transparency, governance frameworks, and a creditable plan are required so that investors can know what will happen with their money.

Tsatsi (2023) states that increased demand for ESG-aligned products and practices from companies is needed to minimise the global threat of climate change, unethical practices, resource depletion, and rising pollution. Developing companies incorporated ESG into their operations, services, and products and aligned their values with their investment choices and strategies. With ESG integration, all opportunities and risks are incorporated into the investment decision-making procedures. Investors' portfolios will benefit from the integration of ESG, as it considers how companies can save the planet, live responsibly while preserving the environment, and secure a future financially. NBI (2022) notes that this transition may preserve the economy, create new green sectors, and secure long-term competitiveness, but it needs to be combined with intended efforts where the entire SA community is included, and developmental needs are met. Actions by individuals alone are not adequate to meet this challenge, and an organised and collaborative approach is required to decarbonise successfully.

2.6.3 British Columbia

Duff (2008) states that the British Columbia Government announced in 2008 that a consumption-based carbon tax will be introduced of CAD 10 per 1 000 kg of CO2 emissions emitted. This figure will increase to CAD 30 by 2012.

This made the British Columbia Government the most aggressive in addressing climate change action. It should be noted that by putting a price on GHG emissions, the British Columbia carbon tax is beneficial as an economic instrument to combat global climate change. Duff (2008) made a few suggestions after his study to make the carbon tax more appealing in a political way.

First, the distributional impact of the tax must focus on fairness that must be accompanied by other measures to compensate for the large and increased tax burdens that are unavoidable, e.g., credit for low-income homes. Second, Duff (2008) suggested that it is risky to introduce a consumption-based tax and not simultaneously a complete emissions or tax trading scheme on the combustion of fossil fuels to deal with GHG emissions from industrial processes and other sources. British Columbia opened itself to allegations that it was placing the burden of carbon tax on individuals rather than big polluters by leaving the regulation of these certain sectors to consequent measures. Third, political feasibility can be enhanced by phasing the carbon tax (Duff, 2008). It is a good way to begin with fairly low rates and increase the rates slowly over time, in accordance with the schedule when the tax was introduced. By doing so, political opposition might be reduced. Fourth, legislative measures can improve the political feasibility of carbon taxes (Duff 2008). Measures must be explained in an understandable manner and strongly defended to prevent the tax from being mischaracterised as a tax increase. Political feasibility can be improved by allocating revenue to investments in renewable energy and energy efficiency. Fifth, Duff (2008) notes, that implementing border tax adjustments can deal with the competitiveness concerns that would enforce carbon taxes on the embedded carbon content of imported goods into the state. This exempt embedded carbon taxes on services and goods exported from the state. Sixth, Duff (2008) concludes that the approval and general support of the carbon tax, as demonstrated by British Columbia and Canada, is dependent on the introduction of this tax, considering the economic conditions of fuel prices. Opposition grew when fuel and/or gas prices increased, and economic conditions weakened in British Columbia and Canada.

2.6.4 Australia

In 2011, the Australian government introduced a carbon tax through the Energy Act of 2011 (Irigoyen, 2017). This program was meant to support economic growth and control emissions by developing clean energy technologies. A carbon tax is one way to regulate emissions in the country, so that polluters will pay a certain amount per 1 000 kg of carbon emitted. Irigoyen (2017) stated that the selected entities had to forfeit one emission unit for every 1 000 kg of carbon emissions produced or emitted.

During 2012 and 2013, carbon units were sold by the Clean Energy Regulator at a fixed price of AUD 23 per unit, and between 2013 and 2014, carbon units were sold at AUD 24.15 per unit. Owners or companies that did not forfeit enough or any units had to pay a "unit shortfall charge". This created a way for companies to forfeit extra units under the system rather than paying a higher charge for unit shortfall.

In 2012, the country's goal of mitigating GHG emissions was partly accomplished by 1.4% which was the largest annual decrease in the previous decade (Irigoyen, 2017). Unfortunately, it increased the electricity cost for residents and companies by about 10%, which resulted in business closures and other economic hardships. This has also caused unemployment. Nearly 75 000 companies paid penalties or carbon taxes through changes to rebates and duties. This cost was then passed on to smaller businesses, customers, and households that experienced increased prices due to the tax.

Irigoyen (2017) notes that there are eight elements that do and do not work by implementing the carbon tax:

- *Clear aims*. There were good aims that were clearly defined as to support the development of the goal to combat climate change, put a price on GHG emissions, and take action to meet the long-term goal of the country.
- *Public confidence*. The public had a long act of confidence. The public was against the carbon tax, as they worried about the increase in electricity prices, fuel, and groceries.
- *Evidence*. There is good supporting evidence that a carbon tax was introduced in countries such as Finland, Denmark, Norway and Sweden.
- *Stakeholder engagement*. There was a fair amount of stakeholder engagement in the policy to represent the environmental groups' views and other people who strongly supported climate change action.
- *Feasibility*. There was good feasibility that aimed to encourage investment in innovation, skills, and capital in new clean energy sources, support jobs, and improve competitiveness.
- *Political commitment*. There was a fair commitment for the carbon tax scheme to be successful in mitigating emissions which would be politically viable.
- *Measurement*. There was good measurement to oversee the carbon tax administration, observe compliance, and assess the emissions of firms individually.
- *Management*. Good management advises and regulates the operation of the carbon price system by agencies (e.g., the Climate Change Authority).

- *Alignment*. There was weak alignment from stakeholders for policy implementation, as the government failed to market the idea, and reviewers saw it more as a liability that would cost households and hurt companies.

2.6.5 China

Li and Colombier (2009) stated that China started to successfully implement energy efficiency in 2007 in residential developments, motivating that a residential development will remain intact for 30 to 50 years before being refurbished or demolished. Therefore, inefficient construction leads to significant climate and energy implications. The same applies to commercial buildings as well. Implementing carbon emission reduction options in buildings will have a variety of benefits (Li and Colombier, 2009):

- Indoor and outdoor air quality will be improved;
- Benefits of social welfare for low-income homes;
- More employment opportunities;
- Improved quality of life and health;
- Greater access to energy services; and
- Improved comfort.

It is believed to be more cost-effective and efficient in implementing the energy efficiency of commercial and residential buildings at the construction stage, as refurbishment of existing buildings might be costly and create social problems. Furthermore, Li and Colombier (2009) states that energy-efficient buildings do not cost more than less efficient buildings when using the life-cycle analysis approach. There can be a reduction in mechanical equipment when optimising building design by integrating passive solar heating, cooling, and passive ventilation. Thus, the building envelope’s incremental cost regarding conventional building practices can be balanced. The only barriers to sustainable approaches are building developers and financiers.

Li and Colombier (2009) are of the opinion the additional energy consumed in manufacturing insulating material will be balanced out over the first five years of residents’ occupancy by energy savings. Improving the building efficiency in China is the most cost-effective way to reduce carbon emissions. Other methods for reducing energy consumption include architectural and urban design, improved building envelope insulation, optimised site planning and design, sustainable urban planning, sustainable orientation, natural ventilation, solar, bioclimatic architecture design, geothermal energy incorporation, and improved mechanical ventilation with enhanced heat recovery systems.

Passive cooling and heating result in the reduction of mechanical equipment and other related costs. PV integrated buildings reduce the bottleneck transference in conventional large-centralised power infrastructure which would improve grid efficiency (Li & Colombier, 2009). These methods can result in the mitigation of building energy consumption while providing advanced thermal comfort. Li and Colombier (2009) notes that for the effective implementation of the Enhanced Envelope Insulation and Double-Glazing Fenestration (Building for Environmental and Economic Sustainability (BEES)) technology, there is a requirement to be implemented with a policy portfolio. Regulatory standards should be complemented by economic instruments to increase the likelihood of energy-efficient techniques and practices.

2.6.6 New Zealand and Other Countries

Scrimgeour, Oxley and Fatai (2004) note that the New Zealand Government find a combination of fuel taxes, carbon taxes and energy taxes favourable. Scrimgeour et al. (2004) study has indicated that the society’s well-being will be improved where there is a tax on a good whose consumption results into a negative external impact. Environmental taxes will reduce the cost to society and achieve an environmentally friendly goal. Furthermore, Scrimgeour et al. (2004) note that a regressive tax can be resolved by introducing transfers or minimising other taxes which may balance out the negative impact of carbon taxes on low-income houses. This is because low-income homes purchase cheaper, less energy-efficient appliances than richer households, which can be related to the commercial side where investors do not want to invest in energy-efficient appliances or equipment installation, and the end users, the tenants of the commercial building, must pay the price that they might not be able to afford. If the government lowered other taxes, the economy would react positively towards these changes (Scrimgeour, et al., 2004).

Li and Colombier (2009) states that the following countries have introduced carbon taxes to their countries prior to New Zealand:

- Sweden
- Italy
- Switzerland
- Netherlands
- Finland
- Denmark
- UK

The above-mentioned countries have taken continuous measurements towards the greater role of the carbon taxes in their economy (Scrimgeour et al., 2004). These countries have three elements for introducing a carbon tax. First, some taxes and subsidies that may be distortionary must be removed or altered. Second, legislation and taxes are restructured to align with environmental aims. Third, carbon taxes were introduced.

Carbon tax may not yield substantial revenues, but it will result into achieving environmental goals rather than economic aims (Scrimgeour et al., 2004). It could be argued that a carbon tax that reduces GHG emissions can be used to reduce labour expenses due to the revenues being recycled back into the industries. Scrimgeour et al. (2004) is of the opinion that the above mentioned is a way a country can cut energy consumption of buildings, remain competitive and create job opportunities.

New Zealand introduced a carbon tax in 2007, where the revenue from the tax is recycled back through the tax system and the government does not plan to use the revenue to improve its financial position. Scrimgeour et al. (2004) found that by introducing, administrating and maintaining carbon tax and other environmental taxes, it resulted in a reduction of both the consumption of fossil fuels and energy consumption have declined. It was found that a carbon tax reduces carbon emissions and energy consumption by between 14% and 18%.

However, Germany, Japan, Belgium and Austria have implemented broader energy taxes. The use of carbon taxes is not prohibited by an international ETS, either domestically or internationally, as the two are mostly seen as competing policy means for mitigating GHG emissions. Tradable permits and taxes put a price on emissions which is equal to all involved parties. Therefore, emission mitigation targets are met at minimum cost (Li & Colombier, 2009).

2.7 Benefits and Disadvantages of a Low Carbon Economy

2.7.1 Net Zero-Carbon Benefits

1. With commitment to the Paris Agreement, countries will achieve the goal of mitigating climate change through the reduction of carbon emissions.
2. Skill levels of professionals and labour will be increased by introducing low-carbon buildings.
3. More employment will be created by manufacturing more low-carbon building materials.
4. Net zero development will become more attractive to future investors and tenants (Laski & Burrows, 2017).

5. Economic development will be stimulated by growth in the renewable energy sector which will lead to a wide spectrum of operational and capital investments, as stated by GBCSA (2019).
6. It will help to encourage investments, including the interest in being more energy efficient and increasing low-carbon technologies (National Treasury, 2018).
7. A significant reduction in operating costs leads to a good return on investment (Laski & Burrows, 2017).
8. Higher quality tenants will be obtained for new zero-carbon developments which will receive more market recognition opportunities as well as increase the value of assets (Laski & Burrows, 2017).
9. South Africa will remain ahead of the curve in the regulation of countries where more demanding building energy efficiency requirements will be updated (Laski & Burrows, 2017).
10. Through the generation of renewable energy, cheaper electricity will be provided and will offset any fiscal contractions as South Africa moves away from fossil fuels, as stated by GBCSA (2019).
11. With more renewable energy, cheaper electricity and less reliance on fossil fuels, South Africa will have fewer electricity interruptions caused by load shedding.

2.7.2 Net Zero-Carbon Disadvantages

1. Amadeo (2020) notes that a carbon tax needs to be introduced slowly, as a sudden increase in tax may shock the economy.
2. Society will react negatively to additional taxes and cause an uprising (Li & Colombier, 2009).
3. Developers or financers may try to find ways to do tax evasion on their commercial buildings (Li & Colombier, 2009);
4. Carbon taxes may affect low-income houses in an unequal manner (Li &Colombier, 2009).
5. The possibility may arise where there could be double taxation between the carbon tax and labour tax (Scrimgeour et al., 2004);
6. By introducing carbon tax, it might create more misrepresentations due to the extent by which the carbon tax or environmental changes might affect prices the end-users have to pay (Scrimgeour et al., 2004);
7. The government may not obtain substantial revenues from carbon taxes (Scrimgeour et al., 2004);
8. Carbon tax might be regressive; increasing the cost of fossil fuels creates a burden on low-income homes (Amadeo, 2020).

9. Low-income homes pay a greater percentage of their earnings for essentials (such as food, electricity and fuel), and they are not able to afford the switch to electric vehicles (Amadeo, 2020).
10. The economy will not be able to survive if there is an increase in fuel, groceries and electricity costs, as the economy is already fragile due to the pandemic.

2.8 Summary

The literature review identified the need for net zero-carbon buildings, the goal of the WorldGBC, how carbon tax will be implemented in SA, the advantages and disadvantages of carbon tax and how carbon emissions are managed or dealt with in other countries. Fifty office developments, including both newly constructed and retrofitted buildings, have been identified and chosen based on climate conditions similar to those of South Africa annexed hereto which will be used in the research finding to build a basis for the South African office building model.

The world has started to move towards a net zero carbon community; however it must be noted that some net zero carbon buildings are offset by Renewable Energy Credit (REC) or Carbon credits.

The literature review can be used to determine whether zero-carbon buildings will become a reality in SA and what the influence of the carbon tax will be in the country. These findings are discussed in addition to those from the structured interviews in Chapter 4.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Horn et al. (2018), states that the construction sector which maintains infrastructure and builds new housing, is one of the largest GHG emissions contributor causing climate change. Initial investigations indicate that SA might not reach the 2030 and 2050 goals of the WorldGBC in time due to the COVID-19 pandemic weakening the economy and lack of awareness of carbon tax throughout the country. This chapter explains the research design and methodology in detail. Various research methodologies are identified. However, one research methodology was chosen and described the reason for this specific research methodology choice is given.

3.2 Research Design

3.2.1 Introduction

Sileyew (2019) states that research design is intended to provide researchers with a suitable framework for their study. The research design determines how necessary information is obtained. Research design normally falls within one of the following three categories (Marczyk, DeMatteo & Festinger, 2010):

a) *Experimental*. The design is randomly assigned to different conditions.

b) *Quasi-experimental*. There are several groups of measurement used, but the design is not randomised.

c) *Non-experimental*. No groups of measurements are used, and the design is not randomised.

This study will be non-experimental, as the research design is not randomised, and no groups of measurement are used.

3.2.2 Research Method

Data collection techniques included quantitative, qualitative and a mixed-method approach.

3.2.2.1 Quantitative data research approach

Quantitative research comprises of a variety of methods that use a methodical investigation of social phenomena (e.g., numerical or statistical data) (Watson, 2015). This research entails measuring and accepting that the phenomenon under study can be measured. Data in quantitative research are presented by statistics (e.g., graphs, bar charts and percentages).

Sukamolson (n.d.) lists a few examples of quantitative research:

i. Survey research includes in-person and telephone interviews, omnibus surveys as well as self-administered questionnaires.
ii. Correlation research is conducted when the relationship between two or more variables is researched.
iii. Experimental research is conducted in which two or more variables are analysed or groups are examined under different conditions.
iv. Causal-comparative research is where dependent and independent variables' relationships are characterised by a cause-effect relationship.

3.2.2.2 Qualitative data research approach

Seers (2012) defined qualitative research as data that comprises non-numerical data (e.g., words, video or text that might include images). This study uses a detailed and methodical approach with the aim of answering questions based on how people feel, what they think or what something is like (observations, emotions and reactions). This type of research includes a wide range of methodological and philosophical foundations. Qualitative research data were collected through interviews and participant observations.

3.2.2.3 Mixed-method research approach

This research approach is the latest in which quantitative and qualitative research approaches are combined into a mixed-method approach. Grbich (2013) states that a mixed-method approach will provide the best answers to a researcher's research question. Bulsara (2015) defines a mixed-method approach as integrating quantitative and qualitative approaches that involve sequential or simultaneous use of these two methods to follow a line of enquiry and produce new knowledge. For this research, a mixed-method approach is adopted as a research philosophy, where quantitative and qualitative research are combined to answer the main and sub-problem questions from several perspectives and the data collection to have greater validity. Questionnaires will include respondents' perceptions/opinions and their responses will be converted into numerical data. Data collection will be in the form of survey research (structured questionnaires and in-person interviews) and correlation research (the relationship between carbon tax and net zero-carbon office buildings), as well as respondents' opinions and/or reactions toward the questions of the questionnaires.

Data collection techniques include data collected through questionnaires, expert opinions and desktop studies (Sileyew, 2019). Villegas (2023) defines desktop studies as data collected from published journals, reports and related documents that are accessible through websites, public libraries, etc.

Prescriptive Analysis was used as it combined the used of previous analyses in order to determine the solution to the current problem statement, (Gibson, 2021). This research approach comprises a comprehensive literature review, where data are collected from various resources (e.g., books, articles, journals, webinars, websites, reports, libraries and case studies) for analysis. A desktop study will be conducted in the form of a literature review to obtain existing research and data to form a basis for understanding net zero-carbon buildings, carbon tax, how carbon emissions can be managed, and the advantages and disadvantages of becoming net zero-carbon. This is done to obtain a better understanding of the influence on developers who owns an office building portfolio in SA when a carbon tax is implemented.

3.2.3 Research Problem

3.2.3.1 Main Research Problem

From the literature review, it was noted that some SA developers and clients had already started to implement green sustainable products in their buildings. However, the awareness of carbon tax in the country was not yet at a level where developers and clients were aiming to be zero-carbon by 2030 and 2050. At present, the problem in SA is that the public is not yet exposed enough to zero-carbon buildings and carbon tax to ensure that GHG emitters transition to net zero-carbon buildings in time. Currently, exposure comes only from the GBCSA and interested parties. Therefore, not enough people are aware of the situation to ensure a commitment towards change to meet the 2030 and 2050 goals. Therefore, SA might not reach the WorldGBC goals without promoting net zero-carbon buildings and implementing a carbon tax in time to ensure that all buildings will be net zero-carbon buildings.

Other barriers to implementing carbon tax could be:

- The economy remains recovering from the COVID-19 lockdown imposed by the government;
- No confidence or resistance from the community;
- An unwillingness to pay the carbon tax fees;
- People continuing or increasingly working from home resulting in offices being less occupied by tenants which might lead to developers being unwilling to refurbish their buildings into zero-carbon office buildings; or
- An unwillingness from developers to develop new office buildings that will remain at less than half their capacity.

The main research question will be answered by obtaining data from the literature review, structured interviews and questionnaires.

3.2.3.2 Sub-Research Problem 1: Are net zero-carbon buildings a reality in SA?

The first sub-problem/question seeks to determine whether net zero-carbon buildings will become a reality in SA. This sub-problem/question will be answered through data obtained from the literature review and structured interviews with developers and stakeholders.

3.2.3.3 Sub-Research Problem 2: Will developers resist paying a carbon tax or converting their buildings to net zero-carbon?

The second sub-problem/question relates to resistance towards carbon tax and net zero conversions on SA developers and owners. This sub-problem/question will be answered through data obtained from the literature review and structured interviews with developers and stakeholders.

3.2.3.4 Sub-Research Problem 3: What measures should be taken to implement new and existing net zero-carbon office buildings?

The third sub-problem/question asks what measures must be taken to implement new and existing net zero-carbon office buildings. This sub-problem/question will be answered using data obtained from the literature review and the Carbon Efficient Office Building Model.

The research aims of this study are:

- To conduct a literature review to determine whether net zero-carbon buildings will become a reality and the influence of carbon tax in SA;
- To determine what the goals of the WorldGBC would mean for SA;
- To collect data on the current state of net zero-carbon office buildings and the carbon tax in SA;
- To collect data on the current state of net zero-carbon office buildings and the carbon tax implemented in other countries;
- To analyse the data collected to identify the influence of carbon tax on SA developers and property owners; and
- To determine what measures to take by creating a zero-carbon building model for new and existing office buildings that will lower the influence of carbon tax;

Points 1, 2, 3 and 4 in the above list are related to the research conducted in Chapter 2 through the literature review. Point 3 is an essential part of the study. Current knowledge and input from relevant stakeholders and developers are required to collect data and form part of the bigger picture, in combination with Chapter 2.

To obtain inputs from a selection of current developments/property owners, structured interviews will be conducted comprising a questionnaire that respondents will receive beforehand to efficiently make use of the respondents' time. Point 5 is addressed in Chapters 4 and Point 6 in Section 5. The structured interviews/questionnaires, as well as the data gathered from the literature, will solve the main research problems and sub-problems.

3.3 Research Methodology

3.3.1 Introduction

This study's research approach will comprise a comprehensive and detailed literature review to determine the influence of carbon tax on developers developing new and/or owning existing office buildings and to identify ways to reduce the impact of carbon tax on these office buildings compared to other countries. Structured interviews will be conducted with developers/property owners owning office buildings who would be affected by carbon tax and consultants who specialise in net zero buildings and carbon tax to determine the influence of carbon tax. This will be done to identify whether there are any negative impacts of the carbon tax on the country or whether it is sufficient to encourage developers, investors and property owners to transition to net zero-carbon office buildings.

3.3.2 Proposed Research Strategy

The proposed research strategy determines the influence of carbon tax on developers owning existing and developing new commercial buildings. This will be achieved by identifying whether the WorldGBC's goals could be achieved, and testing the hypotheses of whether SA could meet these goals and what the impact of carbon tax would be by analysing the data obtained from the mixed-method research approach. After data analysis, strategies can be formulated to reduce the impact of carbon tax in the country by creating a lower carbon office model that would serve as a guideline for developers and office building owners wanting to refurbish their existing office buildings or develop new office buildings that can be EDGE-certified.

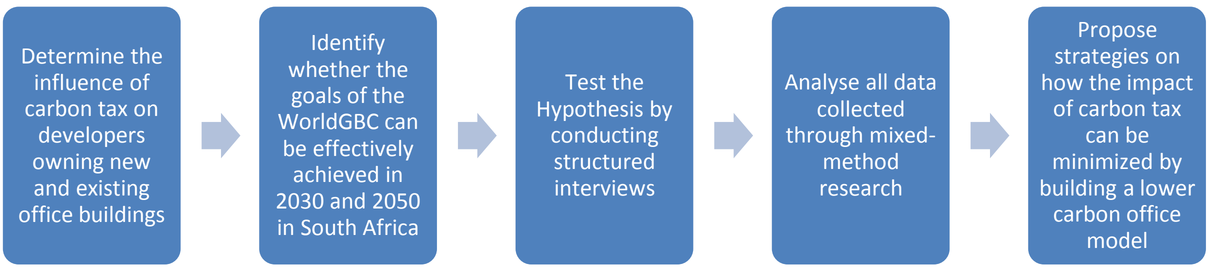

Figure 3.1: Proposed research strategy

3.3.3 Research Instrument

Duquesne University (2020) defines a research instrument as an instrument being used to collect, measure and analyse data related to the research interests. Columbia University (n.d.) provided examples of research instruments:

- checklists
- surveys
- interviews (e.g. structured, unstructured, focus, focus group or non-directive interviews)
- questionnaires
- tests

Observation is defined as a non-experimental research method in which the researcher observes the behaviour of the participants by watching what they do (Columbia University, n.d.). The observations were as follows:

- *Structured observation*. Research is performed at a specific time and place where participants' ongoing behaviour is observed.
- *Natural observation*. Research is performed in a natural environment; the participants' spontaneous behaviour is studied. The researcher will record the behaviour of the participants and how they see it.
- *Participant observation*. When the research is performed, the researcher becomes part of the study group and joins the group to retrieve a deeper insight into the participants' lives.

As discussed, this research methodology will consist of a mixed-method research approach where the main problem and sub-problems/questions will be answered through current information and facts available in the form of historical research and structured interviews/questionnaires conducted, including natural observation to the questions, with developers/property owners and consultants who specialise in net zero buildings and carbon tax to provide more insight to the current matters of SA.

3.3.4 Population and Sample Size

Chadwick (2017) defines a population as events or objects of a specific type where researchers pursue information or knowledge that might be broad or narrow. It comprised a large collection of participants and objects. When it is impossible, expensive, time-consuming or impractical to collect data about each member of the population, a sample size can be used to collect data from a manageable size for observation.

The Institute for Work and Health (2008) describes sample size as the number of participants, objects or observations included in the research that influence the accuracy of the hypotheses and the control of the study to draw conclusions. This study's population is focused on developers and property owners who own commercial buildings and professionals in the construction team for the development of new or renovating existing commercial buildings in Gauteng, SA.

The *Mail & Guardian* (2017) states that a recession in the SA economy led to less bold development in property. Commercial developers were more willing to spend money on investing in existing properties rather than constructing new developments. A large amount of capital is required to develop commercial properties. However, with the current economic state of the country, it is important for commercial developers to discover new ways to obtain tenants or new clients. Owing to COVID-19, a few commercial developers had to close their doors. Co-working spaces, hot desks, flexible working spaces and employees working from home led to vacancies in commercial spaces, which in turn led to reducing some commercial developers or existing developers and their commercial portfolios. Therefore, the prevailing economic conditions in SA, paired with reduced international investment, have played a substantial role in the decrease in property development in commercial spaces for developers. This contributed to a decline in the overall number of commercial developers.

The SA population of developers is complex because some developers focus only on residential, commercial or industrial portfolios. The sample size focuses only on commercial developers identified in Gauteng, South Africa. There are only a limited number of commercial developers in Gauteng, but most of the developers in Gauteng have commercial properties throughout South Africa in their portfolio. Therefore, 17 commercial property developers were identified, including well-known commercial developers ranging from a few to many property portfolios. Although there are only a few commercial property developers, they provide an adequate representative sample size for this research.

Purposive sampling is used, as this is a non-probability type of sampling, where a certain group is studied who are knowledgeable experts (Tongco, 2007). Therefore, the 17 commercial developers were chosen on purpose. Purposive sampling is used in quantitative, qualitative, and mixed research methods, which makes this an ideal sampling method to use in this research.

Nikolopoulou (2023) notes that purposive sampling has a high risk of research biases as it focuses on in-depth on small sample sizes. However, Tongco (2007) motivates that this inherent bias contributes to its effectiveness and when tested against random probability sampling, it will remain robust. However, it is important to choose a competent and reliable participant.

These 17 commercial developers were identified as the sample size because they are best suited to help answer the main research question. To achieve a confidence level of 95% that the true value lies within ±5% of the measured/surveyed value, at least 17 surveys are required. These companies have good property portfolios in the commercial sector, and some are already developing or transforming their buildings into green building-certified assets. The reason for the purposive sample size is that the above developers have a range of small to large portfolios of commercial buildings in Gauteng (some of these developers' portfolios extend to other provinces and countries), which is sufficient for the purpose of this study. There is a limited number of commercial developers in the country, contributing to the small sample size. The company representatives will be contacted via telephone and email asking for their assistance and attaching the structured interview questionnaire to the email to peruse and fill in. Thereafter, a meeting would be arranged to discuss the answers with the relevant company representatives and obtain any further insights they might have concerning the research topic.

Structured interviews were used where the context was prepared before it was sent to participants. Ashfaq (2016) states that structured interviews are fixed design interviews so that the participants will be asked the same questions in the same order to receive a limited range of responses. The reason for using structured interviews is to compare responses easily between participants to identify patterns and areas for future research. George and Merkus (2023) explain that structured interviews reduce the possible biases that might arise and result in less uncertainties in the data analysis, increasing the validity, reliability and credibility of responses.

3.3.5 Data and Data Analysis

The data collected through the interviews and 50 existing commercial buildings EDGE certification data were entered into recruitment logs to successfully track the data. A recruitment log is a complete record of all information acquired from interviews and questionnaires (Marczyk et al., 2010). Note that where the participants gave their consent to participate in the study and no information can be recorded for which the participants have not consented for ethical reasons.

The data must be screened for correctness. When the results from the structured interviews/questionnaires are logged, quantitative research will be analysed using descriptive statistics. Marczyk et al. (2010) explains that descriptive statistics describe the data collected by summarising the data prior to analysing the hypotheses. Then, this data will be displayed in table form and similar or dissimilar data will be presented in pie chart form.

Then, the interview results would be compared with the literature review to identify influences of carbon tax on developers/owners owning office buildings in SA. The analysed data will be used to identify and propose strategies to reduce the impact of carbon tax on new and existing office buildings. The findings from the data analysis would enable the researcher to build a lower carbon office model for new and existing office buildings that would lower the influence of carbon tax and could become EDGE certified to meet the standards of the WorldGBC. Project studies of EDGE from the literature will be used, together with other findings from Chapter 2, to create a basis for this model, which will be refined with the results from the questionnaires and interviews. Practical examples will be used to test the model where EDGE will calculate carbon emissions savings and to determine the link between EDGE certification and carbon tax reduction. Fifty existing commercial buildings in the Project Studies where the climate is similar to SA's climate was selected

3.3.6 Limitations

Jansen (2022) defines limitations as weaknesses in the research where there are factors outside of a researcher's control. Limitations include factors such as access to funding, time, participants, equipment and data. Furthermore, research limitations will reflect the shortcomings of research based on theoretical or practical constraints which will limit the study's conclusion. This study's limitations, are as follows:

- The scope of the study will include for both new and existing commercial buildings;
- Structured interviews will be conducted with developments/property owners who own buildings affected by carbon tax and consultants specialising in net zero-carbon buildings and carbon tax. These property owners and consultants might have been hesitant or too busy to participate in this study, which would have led to a reduction in the sample size.
- There is insufficient literature on net zero-carbon and carbon taxes on office buildings in SA.

3.3.7 Delimitations

Jansen (2022) defines delimitations as the choices the researcher purposefully makes to try or not try to achieve in the research. In other words, the research questions and research aims will be included or excluded.

Furthermore, Theofanidis and Fountouki (2018) describe delimitations as being within the researcher's control, but the researcher decides to limit the research aims and aims that can be achieved.

The study aim is to determine the influence of carbon tax on developers owning office buildings and to identify whether this tax will be sufficiently motivated for developers and property owners, who own GHG-emitting office buildings, to transition to net zero-carbon buildings, or whether carbon tax will not have an influence until it is too late. This study's delimitations are as follows:

- This research will be conducted over a period of three years.
- The study will be limited to developers/property owners operating in Gauteng in SA, but some developers might have commercial buildings in other provinces and/or countries where a low carbon economy is already implemented.
- This study will be limited to exploring only the impact of the first phase of carbon tax on office buildings in SA.
- This study is on commercial buildings that emit carbon emissions, not residential buildings, government buildings (e.g., schools or warehouses).
- The focus will be to create a model for new and existing office buildings that have low carbon emissions which will in turn reduce the carbon tax for developers and how this carbon tax will influence developers if they do not decide to convert their office buildings to have low carbon emissions. Therefore, not focusing on the:
  - *Physical calculation of carbon tax*. The Carbon Tax Act (Act No. 15/2019) details how to calculate the carbon tax for the different type of emissions.
  - *Physical calculation of carbon emissions*. The EDGE application calculates the carbon emissions for different types of buildings based on the data inserted.
  - *How the tax will be submitted to SARS*. This is detailed by SARS on how developers and owners can submit their carbon tax reporting documents and the process involved.

3.3.8 Ethical Considerations

This study involves the participation of human beings. Therefore, four ethical factors must be considered when working with people: (1) protection from harm, (2) right to privacy, (3) informed consent and (4) honesty with professional colleagues (Pietersen, 2017). Research activities regarding this will only be conducted after ethical clearance is obtained from the Faculty of Engineering, Built Environment and Information Technology (EBIT) Faculty Committee for Research Ethics and Integrity.

Study participants will be identified as described in the Proposed Research Approach section and invited to voluntarily participate. Participants will not, at any stage, be forced or feel compelled to answer any questions in this study.

Concerns regarding safety, health and the environment will not be applicable, as this research will not impact the environment or jeopardise the safety and health of people or animals.

Personal information will not be required for this research; no personal details (e.g. the participant's name, age, race, identity number, personal numbers or bank details) will be asked during the interview. Ethical clearance was obtained prior to commencing contact with the participants, sending the interview questions, scheduling meetings virtually or in person and receiving answers. The process of ethical clearance is discussed in Chapter 4.

3.4 Summary

This chapter presents the detailed research design and methodology. Data obtained from sources (e.g., journals, books, webinars, articles and other online sources) provide a broad overview of the impact on carbon tax in a country and what could be done to minimise the effects thereof. However, information is needed from SA developers to obtain a full picture of how a carbon tax would impact developers in this country to conclude what the real problem is and how it can be solved.

Evaluating the Fifty office developments and the current rate of carbon tax in SA from Chapter 2, as well as the structured interviews using the research design and methodology will be explained in the following Chapter.

CHAPTER 4: RESEARCH FINDINGS

4.1 Introduction

An efficient research strategy is needed to gather data to form a good overall picture of the influence of the carbon tax on SA office buildings and how it could be reduced. Data are retrieved from the literature review to form a foundation for understanding the research topic, the main research problem and to identify possible solutions that could reduce the implications of carbon tax. This is substantiated by the questionnaire filled in by the sample size to identify the awareness of the carbon tax in SA.

4.1.1 Ethics Submission and Approval Background

The questionnaire first had to be reviewed and approved by the Research Ethics Committee of the EBIT Faculty at the University of Pretoria (UP). The application form for "Influence of carbon tax on office buildings in South Africa", as well as all the supporting documentation (company permission forms, research proposal approval letter, the questionnaire and informed consent form) had to be submitted via the online Research Grants and Ethics system on the University of Pretoria Student Portal. The initial submission was submitted on 03 November 2022 feedback was received with 'modifications required' where some questions had to be modified or omitted. On 20 February 2023 the revised and modified application form and updated supporting documents were submitted for approval and on 28 May 2023, the Ethical Approval Letter (see Annexure A) from the Ethics Committee was received where ethical clearance was received. Thereafter, the distribution of the questionnaires was commenced, and interviews were conducted.

4.1.2 Questionnaire

Furthermore, the questionnaire was designed to identify the influence of carbon tax on buildings, as it will contribute to examining the current state and situation of carbon tax in this country, as well as assist developers, property owners and managers and other stakeholders with strategies to reduce the impact of carbon tax on their buildings (e.g., strategies such as converting existing buildings into zero-carbon buildings). This study's objective is to identify the influence of carbon tax on buildings and synthesise strategies for reducing the impact of carbon tax on buildings that would be suitable in an SA context. Participation in this study was indicated by a questionnaire administered to the company representative. The questionnaire was attached and sent electronically to the company representative and the duration to complete the questionnaire was about 30 minutes. Participants were contacted telephonically, and follow-up emails were sent if no response was received.

The developer/property owner/representative had to confirm electronically or telephonically whether they would agree to participate in the study. It was communicated that participation was voluntary and respondents could withdraw at any time without penalties. Throughout the survey, their privacy was protected and their participation remained confidential. Othman (2012) provided guidance on how to analyse the data qualitatively and quantitatively, where the qualitative analysis will be dealt with the responses in the form numbers and quantitative analysis will be dealt with in the form of words describing the data of the questions asked and how it is interpreted and processed.

4.2 Data Gathered

4.2.1 Literature Review

Data gathered from the literature review were obtained from Project Studies of 50 EDGE-certified projects (Annexure E: EDGE Certified Projects). These data were used to identify carbon-neutral materials/building methods to create an office building model in SA that promotes carbon emission savings and optimises energy efficiency. This could contribute to long-term cost savings for developers by lowering operational expenses, maintenance costs, other utility expenditures and the carbon tax payable. Then, a case study would be used to compare the office building model to traditional building design to test if the office building model would contribute to carbon emission savings and provide a reduction in carbon tax.

4.2.2 Questionnaire

Answers received from respondents (known as data), were received electronically, sorted and saved on a response folder using Google Forms and OneDrive. Each developer's completed questionnaire could be easily identified. A consolidated Excel worksheet was compiled to easily show the list of responses per question, including the percentage of similar responses. Each response was treated confidentially. Therefore, each participant is labelled as "Response 1, Response 2, Response 3, etc." and respondents' answers are used by way of percentages or numbers. The study was performed within SA borders. Data were collected only from commercial SA property developers, primarily in Gauteng. Therefore, there was control over the quantity and quality of answers received. This creates a good and controlled environment and the amount of data collected can be controlled. All 17 responses and non-responses were noted, collected and will form part of the data analysis.

4.3 Data Analysis

4.3.1 Literature Review: Data Obtained from 50 EDGE-Certified Projects and Their Studies

Data obtained from the literature review were evaluated from the Project Studies of 50 EDGE-certified projects (Annexure E: EDGE Certified Projects). Each project serves as a showcase for the standard optimal energy, water, and material solutions employed to attain EDGE certification and reduce carbon emissions. Given the scarcity of information on net-zero office buildings in SA, an investigation into these 50 international projects was conducted, prioritizing regions with climates akin to or matching that of South Africa. This endeavour is aimed to develop a distinctive and relevant Carbon Efficient Office Building Model tailored specifically for South Africa."

4.3.1.1 New and Retrofitted Buildings

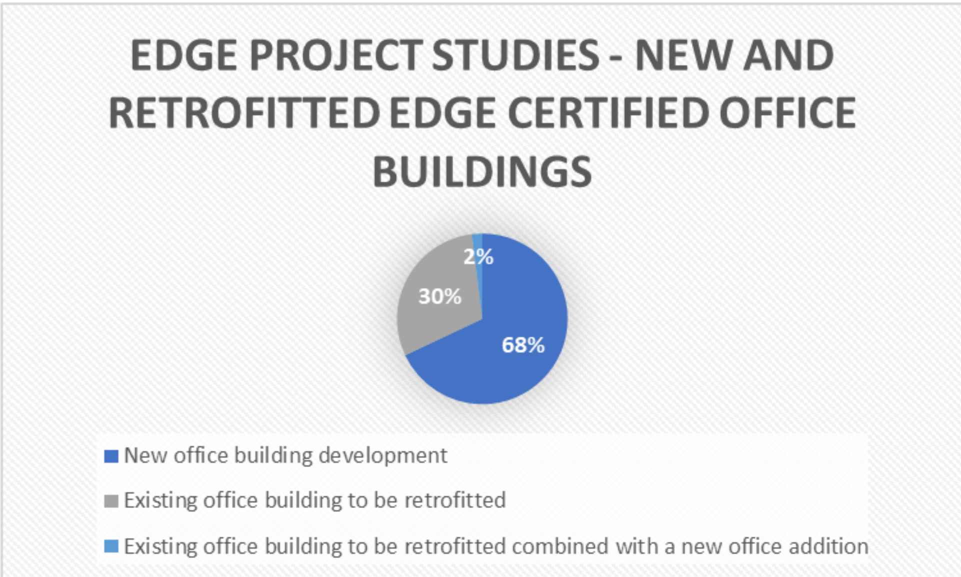

Figure 4.1: New and retrofitted office buildings

Of the 50 EDGE certified office projects listed in the literature review (Figure 4.1):

- Thirty-four (68%) were new developments;
- Fifteen (30%) were existing buildings being retrofitted; and
- One (2%) was an existing building retrofitted together with a new addition to the building.

4.3.1.2 Energy Savings

Table 4.1: Office building elements contributing to the energy savings

	Office building elements	Total number of elements that offices have out of 50 projects	Total percentage of elements that offices have out of 50 projects
	Window to wall ratio		
1	Window to wall ratio is reduced	35	70%
	Shading Elements		
2	External shading elements	21	42%
	Reflective Coatings		
3	External roof with a reflective coating	18	36%
4	External walls with a reflective coating	10	20%
	Insulation		
5	Insulation to the roof	21	42%
6	Insulation to the external walls	11	22%
	Glazing		
7	High thermal performance glazing	20	40%
8	Low-E coated glazing	9	18%
	Cooling Systems		
9	VRV cooling system	20	40%
10	Variable speed drives in AHU	7	14%
11	Air-conditioning with water cooled chiller and energy-efficient air-conditioning systems	5	10%
12	VRF cooling system	4	8%
13	Air economizers used during favourable outdoor conditions	4	8%
14	Sensible heat recovery from exhaust air	4	8%
15	Air-conditioning with air cooled screw chiller	2	4%
16	Ceiling fans in the offices	2	4%
17	Refrigeration cases of higher efficiency	1	2%
18	Natural ventilation	1	2%
	Energy-saving lighting		
19	External and internal areas consisting of energy-saving lighting	46	92%
20	Staircases and passages have lighting controls	13	26%
21	Open plan offices, bathrooms and conference rooms have occupancy sensors	13	26%
22	Internal areas have daylight photoelectric sensors	7	14%
23	Bathrooms, closed cabins and conference rooms have occupancy sensors	6	12%

24	External and common spaces, as well as passages have energy-saving lighting	3	6%
25	Open plan offices, bathrooms, closed cabins and conference rooms have occupancy sensors	3	6%
26	Bathrooms have occupancy sensors	1	2%
27	Skylights providing 50% daylight to the top floor area	1	2%
	Electricity meters		
28	Smart electricity meters	9	18%
29	Consumption based energy meters	3	6%
	Solar PV		
30	Solar PV	17	34%
	Heated water generation		
31	Spacing has a High Efficiency Condensing Boiler	3	6%
32	Heat pump water generation system	2	4%
	Offsite Renewable Energy Procurement		
33	Offsite Renewable Energy Procurement	3	6%

Abbreviations: air handling units (AHU), low-E (low emissivity), photovoltaics (PVs), variable refrigerant volume (VRV)

4.3.1.2.1 Window to Wall Ratio

Of the 50 EDGE certified office projects listed in the literature review, 35 (70%) reduced the window-to-wall ratio to minimise the energy operational costs. Most projects have a reduced window-to-wall ratio, indicating a favourable element for use in the building model.

4.3.1.2.2 Shading Elements

Of the 50 EDGE certified office projects listed in the literature review, 21 (42%) projects had shading elements installed on the façade and roof to contribute to energy savings. Although only a few projects have shading elements, they are effective elements that radiate sun rays away from the building, reducing heat absorption into the building.

4.3.1.2.3 Reflective Coatings

Of the 50 EDGE certified office projects listed in the literature review:

- Eighteen (36%) projects had reflective coatings on the roof; and
- Ten (20%) projects had reflective coatings on the façade walls to contribute to energy savings.

Reflective coatings on façade walls and roofs are effective elements to reflect sun rays away from the building to reduce heat absorption into the building.

4.3.1.2.4 Insulation in Walls and Roof

Of the 50 EDGE certified office projects listed in the literature review:

- Twenty-one (42%) projects had insulation installed in the roof; and
- Eleven (22%) projects had insulation installed in the external walls to contribute to energy savings.

Insulation in the external walls and roof ensures that heat is conserved during the winter months to reduce the need for heating devices and contribute to energy savings.

4.3.1.2.5 Glazing

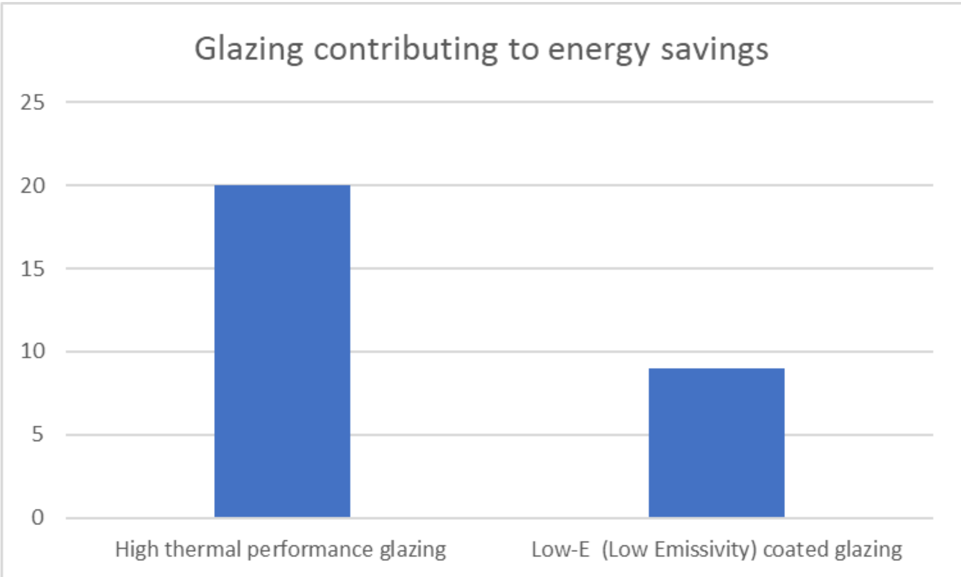

Figure 4.2: Glazing used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty (40%) projects have high-performance glazing installed in the windows; and
- Nine (18%) projects have low-E (low emissivity) coated glazing installed in the windows (Figure 4.2).

Most projects have high-performance glazing, indicating a favourable element for use in the building model.

4.3.1.2.6 Cooling Systems

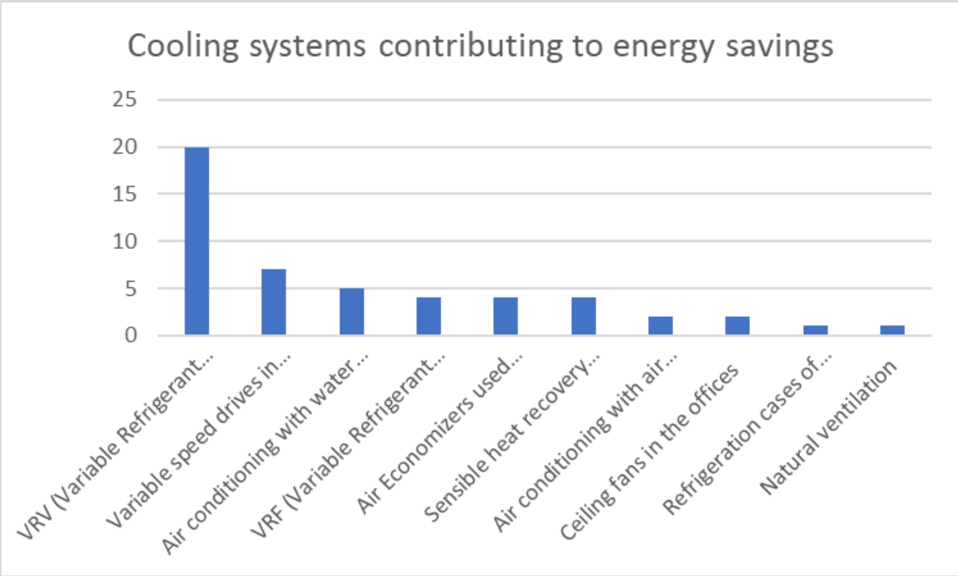

Figure 4.3: Cooling systems used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty (40%) projects have a variable refrigerant volume (VRV) cooling system;
- Seven (14%) projects have variable speed drives in the air handling units (AHU);
- Five (10%) projects have energy-efficient air-conditioning systems or air-conditioning with a water cooler;
- Four (8%) projects have a Variable Refrigerant Flow (VRF) cooling system;
- Four (8%) projects have air economizers used during favourable outdoor conditions;
- Four (8%) projects have sensible heat recovery from exhaust air;
- Two (4%) projects have air-conditioning with an air-cooled screw chiller;
- Two (4%) projects have ceiling fans in the offices;
- One (2%) project has refrigeration cases of higher efficiency; and
- One (2%) project has natural ventilation (Figure 4.3).

Most projects have a VRV cooling system, which is a favourable element for use in building models.

4.3.1.2.7 Energy-Saving Lighting

Of the 50 EDGE-certified office projects listed in the literature review:

- Fourty-two (92%) projects had energy-saving lighting in internal and external areas to contribute to energy savings;
- Thirteen (26%) had lighting controls in staircases and passages;

- Thirteen (26%) had occupancy sensors in the bathrooms, conference rooms and open plan offices;
- Seven (14%) had daylight photoelectric sensors in the internal areas;
- Six (12%) had occupancy sensors in bathrooms, closed cabins, and conference rooms;
- Three (6%) had energy-saving lighting in the external areas, common areas, and passages;
- Three (6%) had occupancy sensors in bathrooms, open plan offices, closed cabins, and conference rooms;
- One (2%) had occupancy sensors only in the bathrooms; and
- One (2%) had a skylight on the top floor to provide natural lighting.

Most projects have energy-saving lighting in internal and external areas, lighting controls in staircases and passages, and occupancy sensors in open-plan offices, conference rooms and bathrooms, indicating favourable elements for use in the building model.

4.3.1.2.8 Electricity Meters

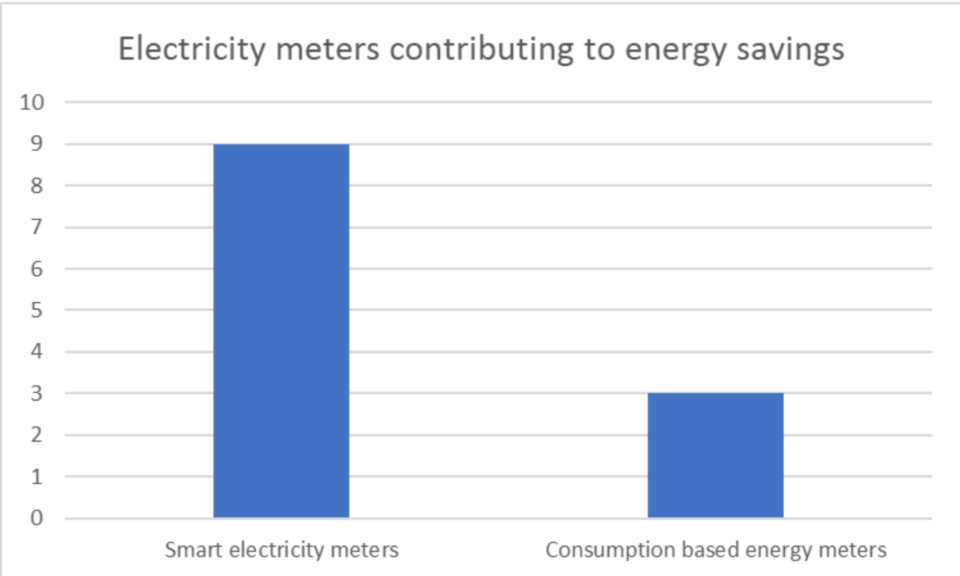

Figure 4.4: Electricity meters used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Nine (18%) projects had smart electricity meters; and
- Three (6%) projects had consumption-based energy meters (Figure 4.4).

More projects have smart electricity meters, indicating a favourable element for use in the building model.

4.3.1.2.9 Solar PVs

Of the 50 EDGE-certified office projects listed in the literature review, 17 (34%) projects had solar PVs installed to minimise operational energy costs. A few projects have solar PVs installed, where sunlight and rays are converted into electricity to lower the costs of electricity, indicating a favourable element for use in the building model.

4.3.1.2.10 Heated Water Generation

Of the 50 EDGE-certified office projects listed in the literature review:

- Three (6%) projects had high-efficiency condensing boilers; and
- Two (4%) projects had a heat pump water generation system installed to minimise the energy operational costs.

4.3.1.2.11 Offsite Renewable Energy Procurement

Of the 50 EDGE-certified office projects listed in the literature review, three (6%) had off-site renewable energy procurement.

4.3.1.3 Water Savings

Table 4.2: Office Building Elements Contributing to Water Savings

	Office building elements	Total number of elements that offices have out of 50 projects	Total percentage of elements that offices have out of 50 projects
	Effective water flush systems		
1	Urinals have effective water flush systems and faucets are water efficient	39	78%
2	Water closets have effective water flush systems	26	52%
3	Water closets have dual flush systems	20	40%
4	Showers have efficient water systems	4	8%
	Faucets and aerators		
5	Bathrooms and kitchen sinks have low-flow faucets	38	76%
6	Bathrooms and showers have low-flow faucets	3	6%
7	Auto shut-off faucets and/or aerators	2	4%
	Water recovery systems		
8	Rainwater harvesting system	12	24%
9	A recycling and black water treatment system.	11	22%
10	Condensate water recovery	4	8%

	Sundry water saving elements		
11	Reduced water usage in the cooling towers	1	2%
12	Water efficient plumbing features	1	2%
13	Smart water meters	1	2%

4.3.1.3.1 Effective Water Flush Systems

Of the 50 EDGE-certified office projects listed in the literature review, 39 (78%) projects had urinals with effective water flush systems and water-efficient faucets (taps in bathrooms and kitchens). Most projects have urinals with water-effective flush systems and faucets that are water efficient, indicating favourable elements for use in the building model.

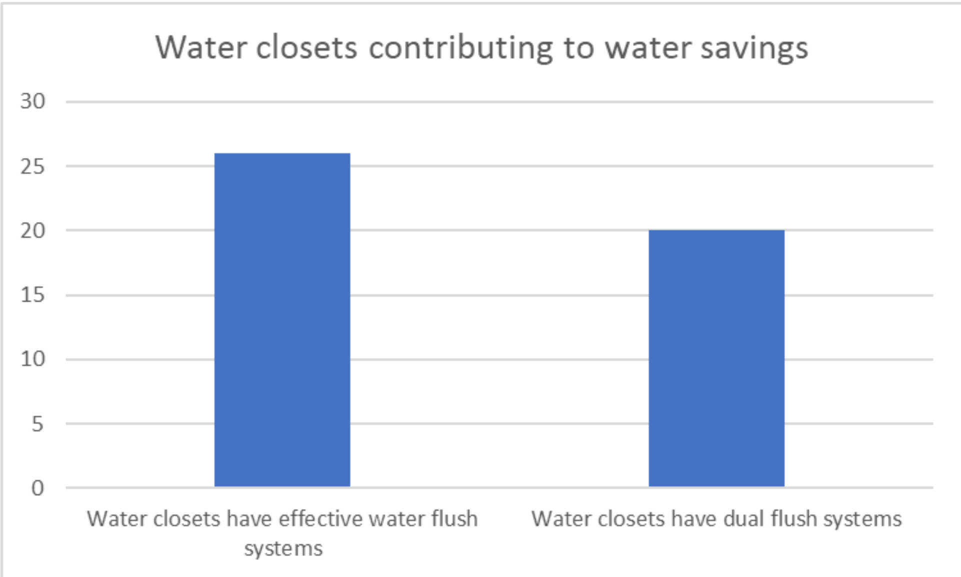

Figure 4.5: Water closets used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty-six (52%) projects had water closets with effective flush systems; and
- Twenty (40%) projects had water closets with dual flush systems (Figure 4.5).

Most projects had water closets with effective water flush systems, indicating a favourable element for use in the building model. Of the 50 EDGE-certified office projects listed in the literature review, four (8%) projects had water-efficient showers.

4.3.1.3.2 Faucets and Aerators

Of the 50 EDGE-certified office projects listed in the literature review:

- Thirty-eight (76%) projects had low-flow faucets in bathrooms and kitchens;
- Three (6%) projects had low-flow faucets in bathrooms and showers; and

- Two (4%) projects had auto shut-off faucets and/or aerators.

Most projects have low-flow faucets in bathrooms and kitchens, indicating favourable elements for use in building models and linking to water-efficient faucets.

4.3.1.3.3 Water Recovery Systems

Of the 50 EDGE-certified office projects listed in the literature review:

- Twelve (24%) had a rainwater harvesting system;
- Eleven (22%) had a recycling and black water treatment system; and
- Four (8%) had a condensate water recovery system.

A few projects had a rainwater system and recycling and black water treatment system, indicating favourable elements for use in the building model.

4.3.1.3.4 Sundry Water Saving Elements

Of the 50 EDGE-certified office projects listed in the literature review:

- One (2%) project had reduced water usage in the cooling towers;
- One (2%) project had water-efficient plumbing features, but did not indicate what these features were; and
- One (2%) project had a smart water meter.

4.3.1.4 Materials Resulting to Savings

Table 4.3: Office Building Materials Contributing to Savings

	Office building elements	**Total number of elements that offices have out of 50 projects**	**Total percentage of elements that offices have out of 50 projects**
	<u>Floor Structure</u>		
1	*In situ* reinforced concrete floor slabs	26	52%
2	Concrete filler floor slabs	8	16%
3	*In situ* waffle concrete floor slabs	1	2%
4	Light gauge steel cassette is used for the floor	1	2%
5	Pre-cast concrete floor slabs	1	2%
	<u>Roof structure and covering</u>		

6	*In situ* reinforced concrete roof slab	22	44%
7	Concrete filler roof slab	8	16%
8	Steel rafter roof construction with steel (zinc or galvanized iron) sheets	6	12%
9	Steel rafter roof construction with aluminium sheets for the roof	3	6%
10	Composite *in situ* waffle concrete roof slab	1	2%
11	Timber rafter roof construction with steel sheets	1	2%
12	Asphalt shingles on steel rafter roof construction	1	2%
13	Ferro cement is used for the roof	1	2%
	Internal and external walls		
	Internal walls		
14	Internal walls — Partitioning	26	52%
15	Internal walls — Medium weight hollow concrete blocks	8	16%
16	Internal walls — Cored bricks	3	6%
17	Internal walls — Cellular light weight concrete blocks	1	2%
	External walls		
18	External walls — Certain walls consisting of aluminium profile cladding	6	12%
19	External walls — *In situ* reinforced concrete	4	8%
20	External walls — Pre-cast concrete	3	6%
21	External walls — Cement fibre boards	2	4%
22	External walls — Steel-clad sandwich panels	1	2%
23	External walls — Polymeric render on concrete blocks	1	2%
	Internal and external walls		
24	Internal and external walls — Autoclaved aerated concrete blocks	10	20%
25	Internal and external walls — Common bricks with plaster and paintwork	6	12%
26	Internal and external walls — Curtain walling	5	10%
27	Internal and external walls — Solid Dense Concrete Blocks	3	6%
	Insulation in walls and roof		
28	Polyurethane insulation in walls	6	12%
29	Polystyrene insulation in roof	3	6%
	Floor covering		
30	Finished concrete floor	12	24%
31	Ceramic tiles	9	18%
32	Stone tiles	5	10%
33	Nylon carpets	4	8%
34	Vinyl tiles	3	6%
35	Terrazzo tiles	1	2%
36	Parquet and wooden blocks	1	2%
	Windows		
37	Aluminium windows	12	24%
38	uPVC windows	2	4%
	Existing building elements kept		

39	The existing internal and external walls are kept as is	13	87%
40	The existing floor and roof construction are kept as is	11	73%
41	The existing flooring is kept as is	8	53%
42	The existing windows are kept as is	8	53%
43	The existing flooring is kept and nylon carpets used	1	7%

4.3.1.4.1 Floor Structure

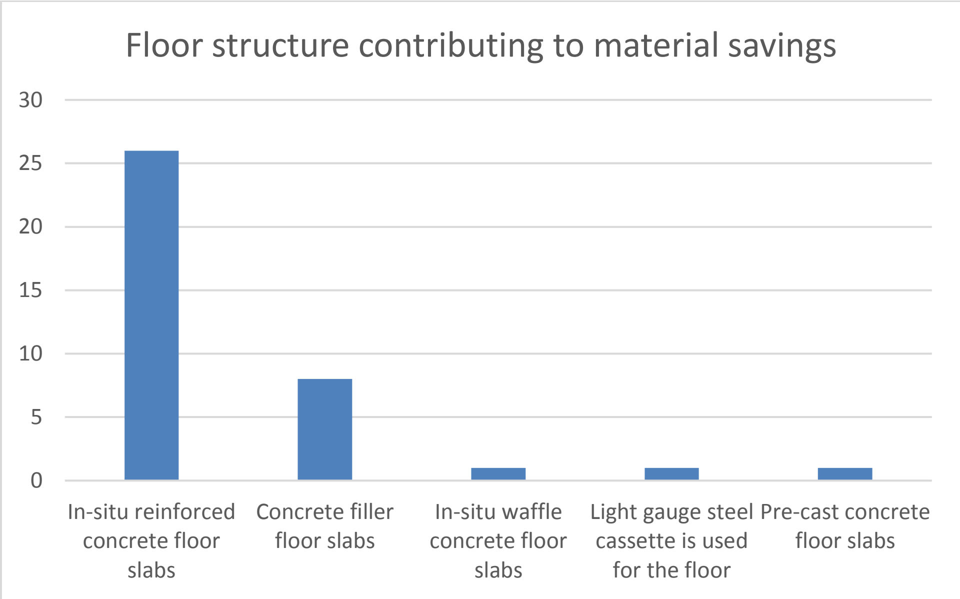

Figure 4.6: Floor structures used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty-six (52%) projects had in situ reinforced concrete floor slabs;
- Eight (16%) projects had concrete filler floor slabs;
- One (2%) project had in situ waffle concrete floor slabs;
- One (2%) project used a light gauge steel cassette for the floor; and
- One (2%) project had pre-cast concrete floor slabs (Figure 4.6).

The majority of projects used in situ concrete floor slabs, indicating a favourable element for use in the building model.

4.3.1.4.2 Roof Structure and Roof Coverings

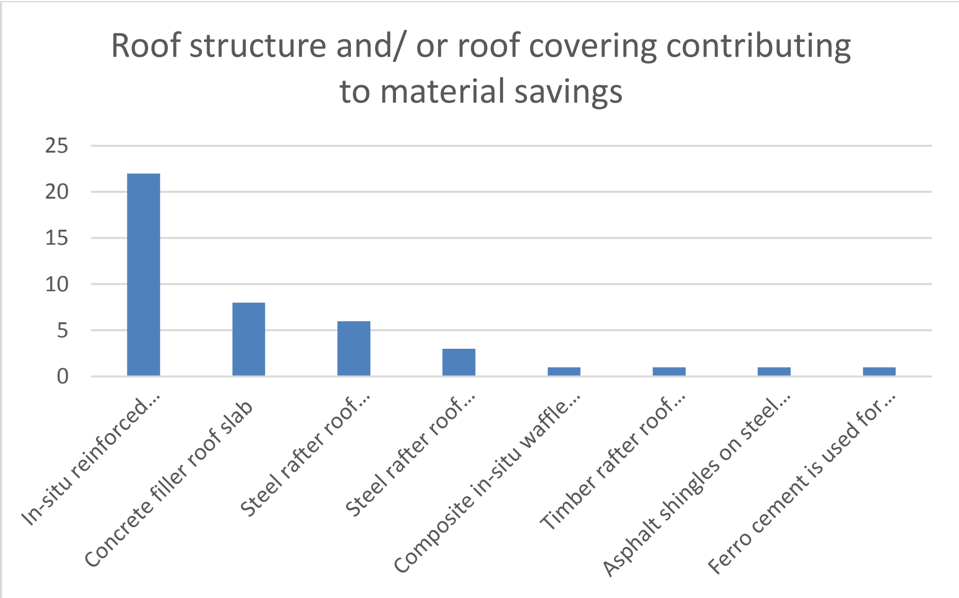

Figure 4.7: Roof structure and roof coverings used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty-two (44%) had in situ reinforced concrete roof slabs;
- Eight (16%) had concrete filler roof slabs;
- Six (12%) projects had steel rafter roof construction with steel roof sheets (zinc or galvanised iron);
- Three (6%) had steel rafter roof construction with aluminium roof sheets;
- One (2%) project had timber rafter roof construction with steel sheets;
- One (2%) project had steel rafter roof construction with asphalt shingles as roof covering; and
- One (2%) project used Ferro cement for roof construction (Figure 4.7).

The majority of projects used in situ concrete roof slabs, indicating a favourable element for use in the building model.

4.3.1.4.3 Internal and External Walls

Internal walls only

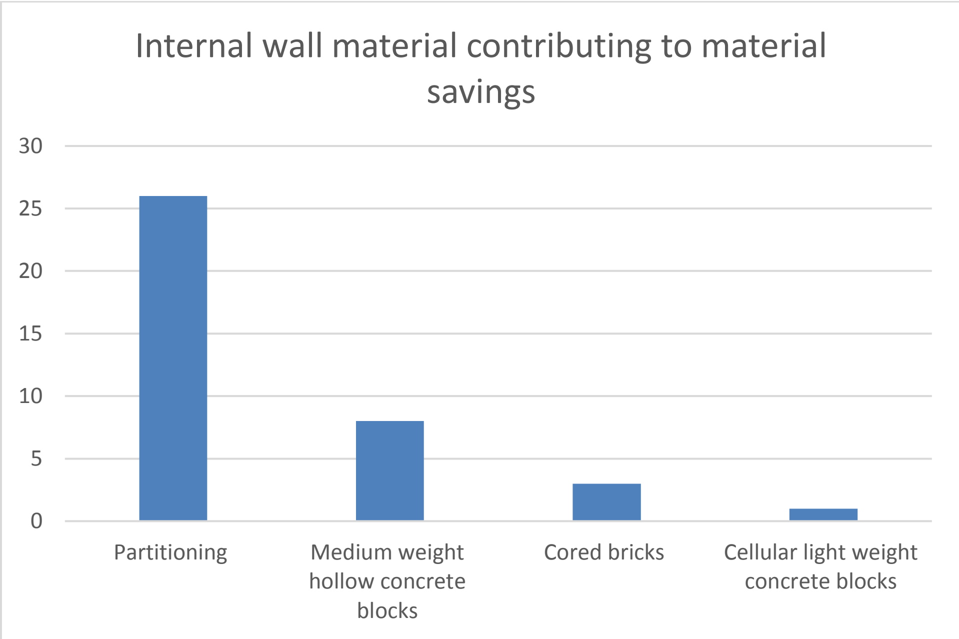

Figure 4.8: Internal walls used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twenty-six (52%) used partitioning for internal walls;
- Eight (16%) used medium-weight hollow concrete blocks for internal walls;
- Three (6%) used cored bricks for internal walls; and
- One (2%) used cellular lightweight concrete blocks for internal walls (Figure 4.8).

External walls only

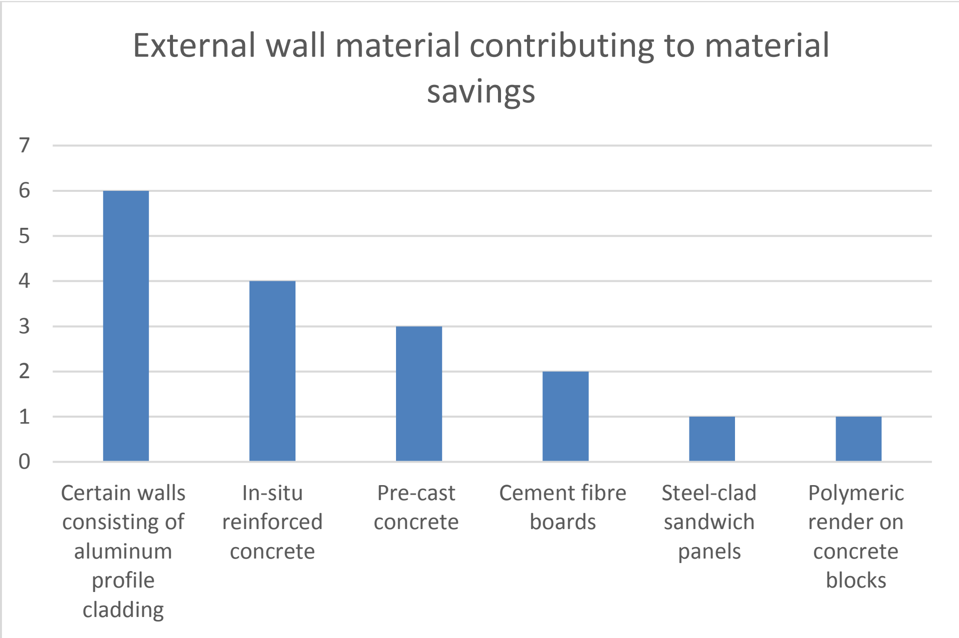

Figure 4.9: External walls used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Six (12%) projects used aluminium profile cladding for some façade walls;
- Four (8%) used *in situ* reinforced concrete for external walls;
- Three (6%) used pre-cast concrete panels for external walls;
- Two (4%) used cement fibre boards for external walls;
- One (2%) project used steel-clad sandwich panels for external walls; and
- One (2%) project used polymeric render on concrete blocks for external walls (Figure 4.9).

Internal and external walls

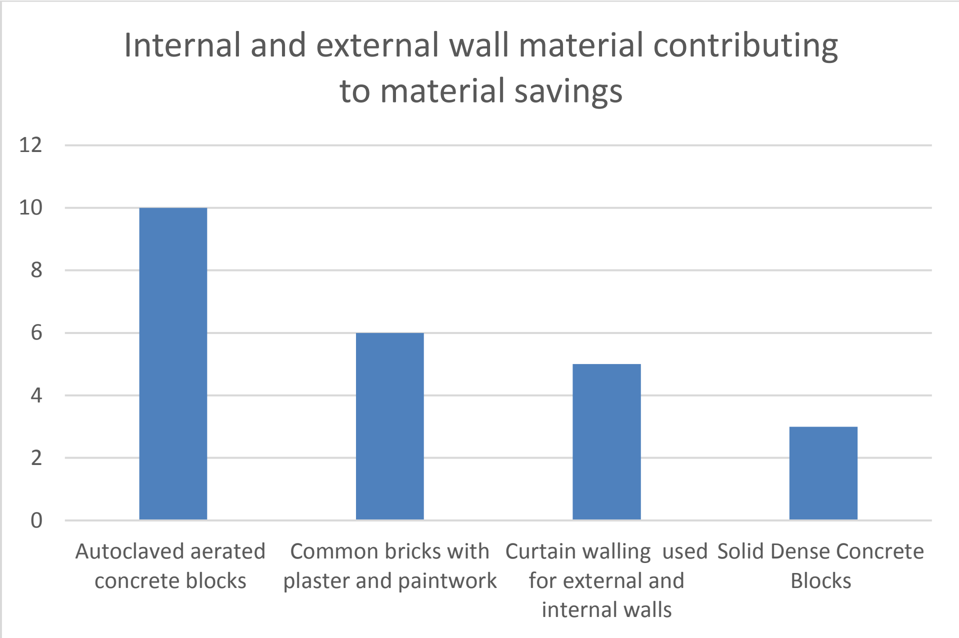

Figure 4.10: Internal and external walls used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Ten (20%) used autoclaved aerated concrete blocks for external walls and load-bearing internal walls;
- Six (12%) used common bricks with plaster and paint for internal and external walls;
- Five (10%) used curtain walling for internal and external walls; and
- Three (6%) used solid dense concrete blocks for internal and external walls (Figure 4.10).

Based on the above majority projects, autoclaved aerated concrete blocks were used for internal load-bearing walls and external walls and partitioning for internal walls, indicating favourable elements for use in the building model.

4.3.1.4.4 Insulation in Walls and Roof

Of the 50 EDGE-certified office projects listed in the literature review:

- Six (12%) used polyurethane insulation in the walls; and
- Three (6%) used polystyrene insulation in the roof.

The insulation used and noted under energy savings and materials indicate that these are favourable elements for use in the building model.

4.3.1.4.5 Floor Coverings

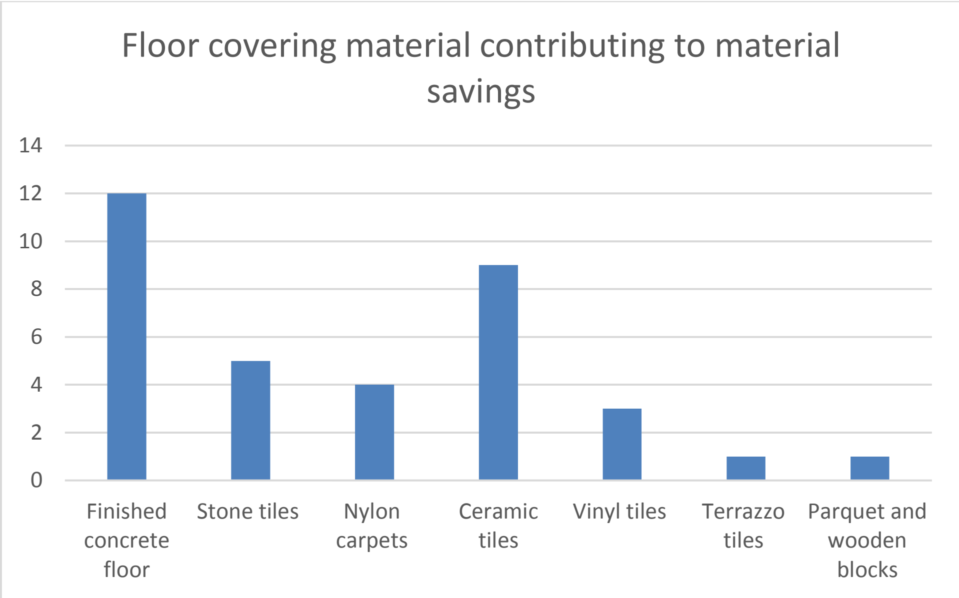

Figure 4.11: Floor coverings used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twelve (24%) projects used a finished concrete floor finish;
- Nine (18%) used ceramic tiles as floor coverings;
- Five (10%) used stone tiles;
- Four (8%) used nylon carpets;
- Three (6%) used vinyl tiles;
- One (2%) used terrazzo tiles; and
- One (2%) used parquet and wooden blocks as floor coverings (Figure 4.11).

The combination of a finished concrete floor finish and ceramic tiles is ideal in a commercial setting and indicates that these are favourable elements for use in building models.

4.3.1.4.6 Windows

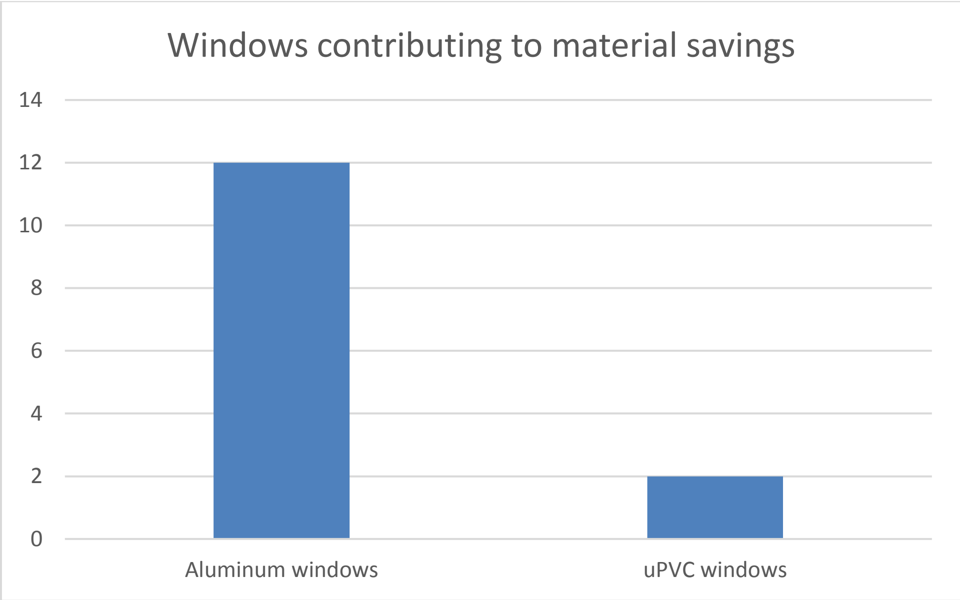

Figure 4.12: Windows used in EDGE-certified projects

Of the 50 EDGE-certified office projects listed in the literature review:

- Twelve (24%) used aluminium windows; and
- Two (4%) used uPVC windows (Figure 4.12).

The majority of projects used aluminium windows, indicating a favourable element for use in the building model.

4.3.1.4.7 Existing building elements kept

Of the 15 EDGE-certified office projects that are being retrofitted:

- Thirteen (87%) kept the existing internal and external walls;
- Eleven (73%) kept the existing floor and roof slab construction;
- Eight (53%) kept the existing floor finishes; and
- Eight (53%) retained their existing windows.

Note that it is favourable to keep the existing internal and external walls, floor and roof slabs, floor finishes, and windows as the majority of existing projects have kept the existing materials as far as possible.

4.3.1.5 Summary

Table 4.4: South African Office Carbon Efficient Building Model Summary That Will Contribute to Savings

	Office building elements	Category
	Window to wall ratio	ENERGY
1	Window to wall ratio is reduced	
	Shading Elements	
2	External shading elements	
	Reflective Coatings	
3	External roof with reflective coatings	
4	External walls with reflective coatings	
	Insulation	
5	Insulation to the roof	
6	Insulation to the external walls	
	Glazing	
7	High thermal performance glazing	
	Cooling Systems	
8	VRV cooling system	
	Energy-saving lighting	
9	External and internal areas consisting of energy-saving lighting	
10	Staircases and passages have lighting controls	
11	Open plan offices, bathrooms and conference rooms have occupancy sensors	
	Electricity meters	
12	Smart electricity meters	
	Solar PVs	
13	Solar PVs	
	Heated water generation *(Optional)*	
14	Spacing has a High Efficiency Condensing Boiler	
15	Heat pump water generation system	
	Offsite Renewable Energy Procurement *(Optional)*	
16	Offsite Renewable Energy Procurement	
	Effective water flush systems	WATER
17	Urinals and faucets have effective water flush systems	
18	Water closets have effective water flush systems	
	Faucets and aerators	

19	Bathrooms and kitchen sinks have low-flow faucets	
	Water recovery systems	
20	Rainwater harvesting system	
21	A recycling and black water treatment system.	
	Sundry water saving elements	
22	Smart water meters	
	Floor structure	**MATERIALS**
23	*In situ* reinforced concrete floor slabs	
	Roof structure and covering	
24	*In situ* reinforced concrete roof slab	
	Internal and external walls	
	Internal walls	
25	Internal walls — Partitioning	
	External walls *(Optional)*	
26	External walls — Certain walls consisting of aluminium profile cladding	
	Internal and external loadbearing walls	
27	Internal and external walls — Autoclaved aerated concrete blocks	
	Insulation in walls and roof	
28	Polyurethane insulation in walls	
29	Polystyrene insulation in roof	
	Floor covering	
30	Finished concrete floor	
31	Ceramic tiles	
	Windows	
32	Aluminium windows	
	Existing building elements kept	
33	The existing internal and external walls are kept as is	
34	The existing floor and roof construction are kept as is	
35	The existing flooring is kept as is	
36	The existing windows are kept as is	

Abbreviation: photovoltaics (PVs), variable refrigerant volume (VRV)

Table 4.4 summarises the elements under energy savings, water savings, and materials used to contribute to carbon emission savings among most of the 50 EDGE-certified projects. The SA office building model was broken down per element.

4.3.1.5.1 Energy

Reduce window to wall ratio

Alsehail and Almhafdy (2020) define window to wall ratio as "the ratio of clear glass to the area of the wall from floor to floor outside". Windows affect an office building's performance by way of energy consumption for cooling or heating, as well as thermal comfort. The ideal overall window-to-wall ratio is 30%. Alsehail and Almhafdy (2020) found that the ideal window to wall will be between 39% and 40% in the north, northwest, and southeast directions, between 10% and 35% in the south direction, and between 10% and 15% in the east and west directions. Therefore, if an office building has a window-to-wall ratio greater than 30%, the ratio should be reduced.

Shading elements

External shading elements can be used as aesthetic features for buildings while minimising sunlight exposure, which increases the building temperature. Atzeri, Cappelletti and Gasparella (2014) noted that external shading devices enhances thermal comfort but may affect the natural lighting that will cause the increased use of indoor lighting.

The IFC (2017) states that a shading factor equivalent to 1/3 of the window width and 1/3 of the window height on all windows of the building is used by EDGE. These external shading devices are ideal for preventing solar radiation through windows. The ideal combined (horizontal and vertical shading) average shading factor for South Africa is 0.48. The IFC (2017) notes that horizontal shading is used on the north or south façade of the building (especially during the midday of summer or when the sun is high in the sky), vertical shading is used where the sun is low in the sky, combined shading devices (horizontal and vertical) are ideal during most weather conditions throughout the year, and moveable shading devices minimise heat loss during the night and to control sunlight during the day, as well as protect windows from rain, wind, and hail.

Reflective coatings on roof

The IFC (2021) states that reflective paint with a highly reflective finish will lessen the load on air conditioners to cool office spaces while improving thermal comfort in spaces that are not air-conditioned. A reflective finish is measured by way of Solar Reflectivity factors ranging from nought to one, where nought is darker colours, for example, black, and one is bright colours, for example, white. The higher the factor, the better the reflective capacity. The following materials/coatings have favourable Solar Reflectance Index (SRI) factors for use in a project (IFC, 2021) (Table 4.5).

Table 4.5: The following materials/coatings have favourable Solar Reflectance Index (SRI) factors for use in a project (International Finance Corporation, 2021)

Roofing elements	Coating	SRI
Bitumen	Bitumen with a white granular surface	28
	Firestone Styrene-Butadiene-Styrene (SBS) Bitumen with a white coating	28
Asphalt Shingles	Terracotta coloured asphalt shingles with a cool coating	56
Steel Roof	White coloured steel roof	82
	Steel roof with a cool coating	92
Built-up Roof	Built-up roof with a white coated gravel	79
Roof Tiles	Concrete tiles that are white	90
Ethylene Propylene Diene Terpolymer (EPDM)	White coloured EPDM	84
Roof Coatings	White coloured coatings (1 coat)	100
	White coloured coatings (2 coats)	107

Reflective coatings external walls

External walls with reflective coatings operate with Solar Reflectivity factors ranging from nought to one. The following materials/ coatings have favourable Solar Reflectance Index (SRI) factors to use in a project as listed (IFC, 2021) (Table 4.6).

Table 4.6: The following materials/ coatings have favourable Solar Reflectance Index (SRI) factors to use in a project as listed (International Finance Corporation, 2021)

Wall elements	Coating	SRI
Steel	Steel with a white coating	82
	Steel with a cool coating	92
Bricks	Red clay bricks	36
Concrete	Concrete with a red coating	17
	Uncoated concrete finish	25
	Concrete with a white coating	90

Insulation in walls and roof

Insulation is used to avoid heat being transmitted from the outdoor environment into the building during warm weather conditions and vice versa during cold weather conditions (IFC, 2021). The thermal performance was measured using the U-values. Conduction minimises the transmission of heat by using insulation, meaning that a lower U-value will be obtained by using more insulation, as well as better performance. The heating and cooling requirements of an office building are less well-insulated, IFC (2017).

A U-value of 0.45 W / m^2 K is ideal for an energy-efficient building, and the following insulation thickness is needed to achieve the required U-value (IFC, 2021):

Table 4.7: the following insulation thickness is needed to achieve the required U-value (International Finance Corporation, 2021)

Insulation Material	Average thickness (mm) to achieve 0.45 W / m^2 K	Average Thermal Conductivity (W / m K)
Polyurethan (PU) insulation	60	0.029
Phenolic Foam (PF) insulation	48	0.023
Polyisocyanurate (PIR) insulation	50	0.025
Vacuum Insulation Panels	15	0.008
Fibre and Wool	95	0.046
Extruded Polystyrene (XPS) insulation	65	0.031
Expanded Polystyrene (EPS) insulation	78	0.038

Glazing

High thermal performance glazing, for example, double- or triple-coated glazing, is ideal for good thermal performance as the transfer of heat is minimised, where the Solar Heat Gain Coefficient (SHGC) is low. The IFC (2021) indicated that a low U-value and SHGC are preferable for ideal indoor conditions. The SHGC ranges between nought and one where the solar radiation is transmitted through the window. Furthermore, the IFC (2021) notes that the Visible Transmittance (VT) is the percentage of light that passes through the glass, for example, where a glass has 80% VT and 80% visible light is transmitted through the glass. The following glass designs are ideal for use in office buildings (IFC, 2021):

Table 4.8: The following glass designs are ideal for use in office buildings (International Finance Corporation, 2021)

Type of glass	Colour	Coating	Thickness (mm)	Average SHGC	Average U-value (W / m^2 K)	Average VT (%)	Performance
Single glass	Gold	Hard (Pyrolytic)	6 (Double)	0.45	2.76	70	Medium solar control
	Gray	Hard (Pyrolytic)	8	0.32	3.24	70	Good solar control
	Clear	Hard (Pyrolytic)	8	0.51	3.23	70	

Cooling systems

A building can be cooled in various ways, one of which is natural ventilation (IFC, 2021). Natural ventilation is ideal for the offices, passages, and lobbies of commercial buildings. Although Table 4.4 identified VRV cooling system as the favourable cooling system, there is not an option in the EDGE certification application to enter, IFC (2017). By considering the Coefficient of Performance (COP) of a cooling system, a cooling system requires a COP close to or greater than 4.45 to be energy efficient. Therefore, the Variable Refrigerant Flow (VRF) system was selected as the second most favourable option (IFC, 2021). A VRF is a preferable option for use in an office building because it can provide different thermal modes across multiple zones, and the condensing units have numerous indoor units that can be operated separately. The following VRF systems are ideal for use in office buildings (IFC, 2021) :

Table 4.9: The following VRF systems are ideal for use in office buildings (International Finance Corporation, 2021)

VRF system	COP
VRF that is air-cooled < 19 kw	3.81
VRF that has a groundwater source <40 kw	4.75

Energy-saving lighting

To qualify for energy-saving lighting, a minimum of 90% of lamps need to be an effective type of lamp for indoor and outdoor areas (IFC, 2021). All internal areas in a commercial building need to have efficient lighting, for example, lobbies, bathrooms, offices, passages, and storage areas. Outdoor areas that require a minimum of 90% efficient lamps are common, IFC (2017). Efficient lighting can be measured as watt/square meter (W/m^2) which is the energy draw quantity per square meter (a lower quantity is preferable), or lumens per watt (lm/W) which is the lumens per watt of energy draw, is used to measure lighting efficiency to create visible light (a higher efficiency is preferable) (IFC, 2021). For example, if a 20 W light bulb has an energy draw of 20 W that creates 225 lumens, the efficiency will be 225/20 or 11.25 lm/W. The following lamp types are ideal for use in office buildings (IFC, 2021):

Table 4.10: The following lamp types are ideal for use in office buildings (International Finance Corporation, 2021)

Lamp Type	Average Range of Efficiency (lm/W)	Average lifetime (hours)
Light Emitting Diode (LED)	50 – 100	15 000 – 50 000
Metal Halide	50 – 115	3 000 – 20 000
High Pressure Sodium	50 — 124	29 000

Electricity meters

Electricity meters, also known as smart meters, provide tenants and landlords with real-time information on their energy consumption. The IFC (2021) states that these smart meters may provide data on the quantity of electricity or gas consumed, related costs, and GHG emissions emitted through their energy consumption.

Solar PVs

The IFC (2021) describes solar PVs as a renewable energy source for use in building operations that can replace fossil-fuel-based electricity. This is known as an on-site renewable energy source and must be situated on a project site or building. Furthermore, the IFC (2021) states that solar PVs are used to minimise the electricity produced from fossil fuels (e.g. coal). The combustion of fossil fuels leads to carbon emissions, and renewable energy reduces this combustion and the amount of energy required from the grid.

Heated water generation

Heated water generation can only be claimed when the hot water system is higher than the Edge Base case, IFC (2017). However, this baseline adopts using electricity as a resource and a standard electric water heater with a system of almost 100%. Therefore, a standard water heater did not result in savings. The main goal is to reduce carbon offsets and fuel consumption when warm water is generated (IFC, 2021). The following solutions are ideal for use in an office building (IFC 2021):

Table 4.11: The following solutions are ideal for use in an office building (International Finance Corporation, 2021)

Type	Description
Heat pump water heaters (HPWH)	HPWH deliver efficiencies of more than 100%, due to heat not being produced but transferred.
Boilers	Boilers deliver efficiencies of roughly 98%. Water is heated in a tank with the assistance of a controlled thermostat.
Solar Hot Water	Hot water is generated in pipes with the assistance of solar collectors but is dependent on the availability of solar radiation.

Offsite renewable energy procurement

Offsite renewable energy is the source of new clean energy resources in the electrical grid. The IFC (2021) states that a contract document must be signed for new offsite renewable energy procured and specifically assigned to the building project.

In renewable energy, no fossil fuels are used to generate carbon-free electricity sourced from wind, solar, biomass, or tidal resources. The overall carbon footprint of the office building was reduced, but this did not affect the operational CO_2 savings of the building, IFC (2017).

4.3.1.5.2 Water

Effective water flush systems

The IFC (2021) states that water closets will be efficient when a dual flush mechanism is installed; however, a single flush mechanism can be installed with a flush rate of less than 6 L/flush. A dual flush system reduces the amount of water used to flush waste when a full flush is not required. Urinals are required to have a flush rate of 4 L/flush or less (ideally 2 L/flush) to resourcefully use water and ensure that the user is satisfied with the flushing performance.

Faucets and aerators

Kitchen sinks will be water-efficient when it is a low-flow mechanism, the amount of hot and cold water is minimised, and it will reduce the electricity consumed to produce heated water. Low-flow kitchen sinks must be less than 6 L/min (IFC, 2021). The auto-shut-off valves and aerators for washbasin taps minimise water usage but do not influence functionality. A lower flow rate results in efficient water savings. Water-efficient wash basin taps require a flow rate of 2 L/min or less.

Water recovery systems

A rainwater harvesting system can be used as a water efficient system where rainwater is collected and recycled on-site to minimise municipal water consumption (IFC, 2021). Another solution suggested by the IFC (2021) that can be used in conjunction with a rainwater harvesting system or separately is a wastewater treatment and recycling system. Grey water is described as wastewater obtained from showers, kitchens, and hand basin taps. Black water includes grey water as well as solid waste from kitchens and water closets. Grey and black water is recycled through treatment and then repurposed on site to reduce the municipal water consumption. Both systems provided recycled water that could be used for landscaping irrigation, flushing of water closets, cleaning the building, or for air conditioning.

Sundry saving elements

The IFC (2021) notes that smart water meters can be installed to reduce the water consumption of buildings. Smart water meters are not to be confused with prepaid water meters.

Smart meters use an online system that monitors the building's water consumption, showing readings and data from the previous hour, previous day, last 7 days, and 12 months. These meters were installed with the goal of creating awareness of water consumption and reducing water demand.

4.3.1.5.3 Materials

Floor structure

The IFC (2021) states that the embodied energy of a building can be minimised using a floor slab that has lower embodied energy. The thickness of the floor structure influences the embodied energy. The following are a few designs to be considered when constructing floor structures (IFC, 2021):

Table 4.12: The following are a few designs to be considered when constructing floor structures (International Finance Corporation, 2021)

Construction method type	Description
In Situ Reinforced Concrete Slab	This is the most common floor slab construction where reinforced steel, sand, aggregate, Portland cement and water is used. The embodied energy is high due to the reinforced steel and Portland cement.
In Situ Concrete with more than 25% Ground Granulated Blast Furnace (GGBS)	This construction has reinforced steel, sand, aggregate, water and Portland cement. However, more than 25% of the Portland cement is substituted with GGBS. On average, between 40%-50% GGBS is used.
In Situ Concrete with more than 30% pulverized fuel ash (PFA)	This construction has reinforced steel, sand, aggregate, water and Portland cement. However, more than 30% of the Portland cement is substituted with PFA (also known as fly ash). The carbon emissions are less when using PFA and reduces the water and air pollution. This method is favourable construction method.
Concrete Filler Slab	Filler materials, like clay tiles, bricks or cellular concrete blocks, are used in the place of concrete. A minimum quantity of concrete is used to bond the reinforced steel. Less steel and concrete are used making it a cost-effective construction method.
Precast reinforced concrete planks and joist system	Precast concrete is used to create intermediate floor comprising of small plank sections, the joist (timber beams supporting the planks) where the in-situ concrete is poured over. This method can be manually produced with using timber moulds and saves time.
Concrete Filler Slabs consisting of Polystyrene Blocks	A polystyrene form is used around the lower tensile are of the slab in combination with precast concrete slabs and in-situ concrete. This is a cost-effective method where the quantity of concrete is reduced.

In-Situ Trough Concrete Slab	This method is similar to a concrete filler slab where the aim is to reduce the quantity of concrete. In-situ concrete troughs are constructed by using void formers, that are removable, around the lower tensile area of the slab. The void formers are removed after the construction of the slab.
In-Situ Waffle Concrete Slab	This is similar to the in-situ trough concrete slab, but comprises in-situ concrete waffles, in the place of troughs, formed by using removable void formers.
Hollow Core Precast Slab	Precast concrete is used to create consecutive longitudinal cavities an effective lightweight hollow-core floor section.
Composite Slim Floor Slabs with Steel I-beams	A precast hollow-concrete floor supported on modified steel beams, instead of down-stand beams. This method minimizes the floor-to-floor heights.
Composite In-Situ Concrete and Steel Deck (Permanent Shuttering)	A profiled steel decking is used where reinforced concrete are poured onto the decking. Reinforcing may be used depending on the required support needed.

From a literature review, it was found that cement produces high carbon emissions during the manufacturing process. The alternatives identified in Chapter 2 include supplementing cement with fly ash or blast furnace slag, altering the curing process of cement, and pumping liquid carbon dioxide into the wet concrete mix to minimise the quantity of cement required or the carbon sequestration of concrete. Steel also contributes to the environmental impact and carbon emissions, as identified in the literature review. Chapter 2 revealed that 90-100% of reinforced steel can be recycled to reduce carbon emissions, or engineered wood products, known as MTC, can be used instead of steel. However, MTC is not a common method for SA. Based on the findings in the literature review, the best possible construction method for the floor structure will be In-Situ Concrete with more than 30% pulverised fuel ash (PFA).

Roof structure and roof coverings

The IFC (2021) states that the embodied energy of a building can be minimised using a roof slab or roof covering that has a lower embodied energy. The thickness of the roof structure influences the embodied energy. The following are a few designs to be considered when constructing roof structures (IFC, 2021):

Table 4.13: The following are a few designs to be considered when constructing roof structures (International Finance Corporation, 2021)

Construction method type	Description
In-Situ Reinforced Concrete Slab	This is the most common roof slab construction where reinforced steel, sand, aggregate, Portland cement and water is used. The embodied energy is high due to the reinforced steel and Portland cement.

In-Situ Concrete with more than 25% Ground Granulated Blast Furnace (GGBS)	This construction has reinforced steel, sand, aggregate, water and Portland cement. However, more than 25% of the Portland cement is substituted with GGBS. On average, between 40%-50% GGBS is used.
In-Situ Concrete with more than 30% Pulverized Fuel Ash (PFA)	This construction has reinforced steel, sand, aggregate, water and Portland cement. However, more than 30% of the Portland cement is substituted with PFA (also known as fly ash). The carbon emissions are less when using PFA and reduces the water and air pollution. This method is favourable construction method.
Concrete Filler Slab	Filler materials, like clay tiles, bricks or cellular concrete blocks, are used in the place of concrete. A minimum quantity of concrete is used to bond the reinforced steel. Less steel and concrete are used making it a cost-effective construction method.
Precast reinforced concrete planks and joist system	Precast concrete is used to create intermediate floor comprising of small plank sections, the joist (timber beams supporting the planks) where the in-situ concrete is poured over. This method can be manually produced with using timber moulds and saves time.
Concrete Filler Slabs consisting of Polystyrene Blocks	A polystyrene form is used around the lower tensile are of the slab in combination with precast concrete slabs and in-situ concrete. This is a cost-effective method where the quantity of concrete is reduced.
In-Situ Trough Concrete Slab	This method is similar to a concrete filler slab where the aim is to reduce the quantity of concrete. In-situ concrete troughs are constructed by using void formers, that are removable, around the lower tensile area of the slab. The void formers are removed after the construction of the slab.
In-Situ Waffle Concrete Slab	This is similar to the in-situ trough concrete slab, but comprises in-situ concrete waffles, in the place of troughs, formed by using removable void formers.
Hollow Core Precast Slab	Precast concrete is used to create consecutive longitudinal cavities an effective lightweight hollow-core floor section.
Composite Slim Floor Slabs with Steel I-beams	A precast hollow-concrete floor supported on modified steel beams, instead of down-stand beams. This method minimizes the floor-to-floor heights.
Composite In-Situ Concrete and Steel Deck (Permanent Shuttering)	A profiled steel decking is used where reinforced concrete are poured onto the decking. Reinforcing may be used depending on the required support needed.
Clay tiles on steel or timber rafters	Clay tiles are placed on timber or steel rafters. Timber rafters have low embodied energy but require regular maintenance, while steel rafters have high embodied energy and good strength and durability properties. The approximate thickness of the steel or timber rafters is 8mm and clay tiles is 10mm.
Micro Concrete Roofing (MCR) tiles n steel or timber rafters	MCR tiles have a lower embodied energy than clay tiles. Theses tiles are light in weight, durable,

	affordable and pleasing to the eye. Due to the light weight of the tiles, the strength of the roof structure can be lower.
Galvanised iron or zinc steel sheets on steel or timber rafters	Zinc sheets are rolled sheets normally used on pitched roofs or as vertical cladding, these prefabricated sheets are light in weight, affordable and easy to install.
Aluminium sheets on steel or timber rafters	Aluminium sheets can be formed to any shape required and more commonly used in construction. However, it is more expensive than steel, have minimal fire resistance, high thermal expansion and embodied energy.
Copper sheets on steel or timber rafters	Copper sheets have low maintenance as it does not need to be painted or receive a finishing, it has low life cycle costs, more economical and has a long lifecycle.
Asphalt shingles of steel or timber rafters	Asphalt shingles are used for sloped roofs with a slope 1:6 or higher.
Aluminium-clad sandwich panel	These panels are low in weight, can be used in various applications and has a superior structural rigidity.
Steel-clad sandwich panels	These panels are stronger than the aluminium-clad sandwich panels, but also are low in weight, have superior structural rigidity and can be used in various applications.

As described under the floor structure, the best possible construction method for the roof structure is In-Situ Concrete with more than 30% pulverised fuel ash (PFA) when considering a concrete roof or a roof structure that has low embodied energy, such as MCR tiles on timber rafters.

Internal and external walls

External walls are subjected to an outdoor environment, whereas internal walls are not (IFC, 2021). The internal and external wall types are ideal when they contain lower embodied energy (Table 4.14).

Table 4.14: Wall types to consider (not including finishing on the wall) (International Finance Corporation, 2021)

Wall type	Description
Common bricks that will be finished with internal and external plaster	Fired clay bricks are a commonly used wall type, as it is affordable and readily available, but contains a high amount of embodied energy.
Cored bricks that will be finished with internal and external plaster	Cored bricks are fired clay bricks that have holes containing fewer material per square meter of the wall.
Medium weight hollow concrete blocks	These blocks can be easily managed and light, have good thermal and acoustic insulation and reduces the amount of cement mortar needed for joints due to the size of the block.

Solid dense concrete blocks	These blocks have good acoustic insulation and strength properties but has a high embodied energy.
Autoclaved Aerated Concrete blocks	These blocks have great thermal and acoustical insulation properties, lightweight, durable and fire resistant. Around 25% energy is saved when producing these blocks compared to other concrete blocks.
Compressed stabilized earth blocks	These blocks have good thermal insulation properties, fire resistant, affordable, have low amount of embodied energy and friendly towards the environment.
Precast concrete panels	These panels are commonly used for the envelope of a building. These panels do not transfer loads as support is required but are designed to resist wind.
In-situ reinforced concrete wall	In-situ reinforced concrete walls are commonly used around lift walls and external walls but have a high amount of embodied energy.
Cellular Lightweight Concrete (CLC) blocks	These blocks consist of fly ash, water and a slurry of cement, making it more friendly to the environment.
Aluminium Profile Cladding	Aluminium can be easily cast, fastened, bent, welded, shaped, drilled, etc. into the desired shapes foe aesthetical purposes. However, this wall type has a high amount of embodied energy, low fire resistance, expensive and greater thermal expansion.
Exposed external brick walls with internal plaster	This wall type is the same a brick wall but does not have plaster to the external façade.
Precast concrete sandwich panel	These panels consist of an external leaf of precast panel, an insulating material inside and an inner leaf of concrete power floated. These panels have a low thermal conductivity.
Plasterboards on timber boards	This wall type comprises plasterboards, produced from gypsum plaster glued to levels of particle board or study.
Plasterboards on metal studs	This wall type comprises plasterboards that are fixed to metal studs.
Curtain walls	This is a vertical building element, consisting of glass and aluminium frames, which encloses the façade of the building. It does not support loads or maintain structural integrity.

Insulation to roof and walls

Insulation of the roof and walls can reduce the energy costs of a building, but it is preferable to choose an insulation material that has a low amount of embodied energy (IFC, 2021) (Table 4.15).

Table 4.15: Insulation materials to consider (International Finance Corporation, 2021)

Insulation material	Description
Polystyrene	This insulation can be either Expanded Polystyrene (EPS) or Extruded Polystyrene (XPS), but polystyrene has the most embodied energy of all insulation materials.
Mineral wool	This insulation types can come in different thicknesses. However, as the thickness increases, the thermal insulation reduces and the acoustic insulation increases.

Glass Wool	This insulation comes in different densities, the higher the density the better the sound insulation will be but with reduced thermal insulation. Glass wool is typically used in timber frame walls, insulation for suspended floors or roofs and cavity walls.
Polyurethane	This insulation is used in roof, floor or wall insulation, and can be used as insulation to rigid boarding (e.g. plasterboard).
Cellulose	Different types of cellulose products can be used in various applications, there products include spray applied cellulose, dry cellulose, low dust cellulose and stabilised cellulose.
Cork	This insulation is environmentally friendly and has a low embodied energy.
Air Gap smaller than 100mm wide	Air gaps used as cavities is similar to an insulating material. An air gap acts as a barrier for heat as it is trapped in an air space between the two wall skins due to air being a weak heat conductor.
Air Gap larger than 100mm wide	Air gaps larger than 100mm are not good insulators and encourages convection.

Floor covering

Embodied energy can be minimised using floor coverings that contain lower embodied energy (IFC, 2021). The embodied energy per square meter was determined based on the thickness of the floor cover (Table 4.16).

Table 4.16: Specifications to consider when installing floor coverings (International Finance Corporation, 2021)

Floor covering type	Description
Ceramic tiles	Ceramic tiles are durable and have a long-life cycle. However, it contains a great amount of embodied energy.
Vinyl flooring	Vinyl floor covering is affordable, easy to install, has a long-life cycle and resistant to water. However, it contains a great amount of embodied energy. Hazardous organic compounds can be released after installing vinyl flooring.
Stone tiles	Natural stone tiles, obtained locally, has a lower embodied energy than polished or machine cut stone tiles and can be costly.
Finished concrete floor	Leaving the constructed floor slab exposed or applying cement plaster for a finishing layer, a sealant can be applied to the floor as the floor can chip easily.
Linoleum sheet	Linoleum floor covering contains a low amount of embodied energy and can be used instead of vinyl flooring.
Terrazzo tiles	Terrazzo tiles have a long-life cycle and durable.

Nylon carpets	Carpets are a commonly used floor coverings as it has great acoustic properties. However, it contains a high embodied energy
Laminated wood floor covering	This floor covering can be installed in spaces where underfloor heating is installed or where there are changes in the floor due to moisture conditions.
Terracotta tiles	Terracotta tiles are durable, waterproof and fire resistant. This floor finish is an affordable installation option.
Parquet/ wood block floor covering	This floor covering can be installed in spaces where there is underfloor heating. This is a traditional floor finish option, but not commonly used anymore.
Plant Fibre carpet	This floor covering comprises sisal, seagrass, jute or coir, it is a natural floor covering with a low amount of embodied energy. This floor covering is not durable.
Cork tiles	Cork tiles are durable, has a low amount of embodied energy and has a low impact on the environment.

Windows

The IFC (2021) notes that window frames must be chosen to reduce the embodied energy of the building (Table 4.17).

Table 4.17: Window frames that can be considered
(International Finance Corporation, 2021)

Window frame type	Description
Aluminium frames	Aluminium frames are lightweight, durable, and strong, but have a high amount of embodied energy.
Steel frames	Steel frames have good thermal characteristics but are heavy in weight and need to be protected from rust. Therefore, require regular maintenance.
Timber frames	Timber frames have good insulation properties and affordable, but susceptible to weather conditions. Therefore, requiring regular maintenance.
Unplasticized Polyvinyl Chloride (uPVC) frames	uPVC frames have great thermal properties and do not need to be finished. Therefore, the maintenance is low.

Existing building elements being kept

IFC (2021) states that reusable building elements or materials, such as internal and external walls, floor and roof construction, window frames, and floor coverings, can eliminate the embodied energy of new building materials. This is preferable due to the embodied energy having a zero value, but the building elements/ materials need to be older than 5 years to qualify of being 're-used'.

4.3.1.6 Updated Table Summarised

Table 4.18 indicates an updated South African carbon efficient office building model that incorporated the above findings. This model can also be adopted in countries that have the same climate conditions.

Table 4.18: Updated South African carbon efficient office building model summary that will contribute to savings

	Office building elements	Category
	Window to wall ratio	
1	Window to wall ratio is reduced – *Ideally 30%*	
	Shading Elements	
2	External shading elements – *Having an average shading factor of 0.48*	
	Reflective Coatings	
3	External roof with reflective coatings – *White coloured coating with SRI of 100*	
4	External walls with reflective coatings – *White or Stone coloured coating with SRI ideally higher than 50*	
	Insulation	
5	Insulation to the roof – *95mm thick Fibre and Wool insulation*	
6	Insulation to the external walls – *95mm thick Fibre and Wool insulation or 78mm thick EPS / 65mm thick XPS insulation depending on specialist design*	
	Glazing	
7	High thermal performance glazing – *8mm thick grey glazing*	
	Cooling Systems	**ENERGY**
8	Variable Refrigerant Flow (VRF) cooling system – *with a groundwater source < 40 kW*	
	Energy-saving lighting	
9	External and internal areas consisting of energy-saving lighting – *with LED lamp types*	
10	Staircases and passages have lighting controls – *with LED lamp types*	
11	Open plan offices, bathrooms and conference rooms have occupancy sensors– *with LED lamp types*	
	Electricity meters	
12	Smart electricity meters	
	Solar PVs	
13	Solar PVs — *replacing 25% or more of the annual energy consumption*	
	Heated water generation *(Optional)*	
14	Spacing has a High Efficiency Condensing Boiler — *Delivering 98% energy efficiency*	
15	Heat pump water generation system — *Delivering 100% energy efficiency*	

16	**<u>Offsite Renewable Energy Procurement *(Optional)*</u>** Offsite Renewable Energy Procurement	
17 18 19 20 21 22	**<u>Effective water flush systems</u>** Urinals and faucets have effective water flush systems – *Flush rate of 4 L/flush or lower* Water closets have effective water flush systems – *Flush rate of 6 L/flush or lower* **<u>Faucets and aerators</u>** Bathrooms and kitchen sinks have low-flow faucets – *Kitchen sinks to have a flow rate of 6 L/minute or less and washbasin taps to have a flow rate of 2 L /minute or less* **<u>Water recovery systems</u>** Rainwater harvesting system – *Collecting and recycling rainwater* A recycling and black water treatment system – *Treating wastewater and recycling through treatment to repurpose on site* **<u>Sundry water saving elements</u>** Smart water meters – *To monitor water consumption*	**WATER**
23 24 25 26 27 28 29 30 31 32 33 34 35 36	**<u>Floor structure</u>** In-situ reinforced concrete *with more than 30% PFA* **<u>Roof structure and covering</u>** In-situ reinforced concrete *with more than 30% PFA* **<u>Internal and external walls</u>** **Internal walls** Internal walls — *Partitioning (Plasterboards on metal studs)* **External walls *(Optional)*** External walls — Certain walls consisting of aluminium profile cladding **Internal and external walls** Internal and external walls — *Autoclaved aerated concrete blocks* **<u>Insulation in walls and roof</u>** Insulation in walls – *Glass wool or mineral wool* Insulation in roof – *Glass wool or mineral wool* **<u>Floor covering</u>** Finished concrete floor Ceramic tiles **<u>Windows</u>** Aluminium window frames **<u>Existing building elements kept – *Re-using existing elements eliminates the embodied energy of new materials, as the embodied energy will be nought and is a most desirable option*</u>** Keeping majority existing internal and external walls during renovations Keeping existing floor and roof construction during renovations Keeping majority existing floor coverings during renovations Keeping existing windows during renovations	**MATERIALS**

Abbreviation: photovoltaics (PVs)

4.3.2 Case Study: Testing the Carbon Efficient Office Building Model

As identified in the literature review, it takes less than 30 minutes to design a resource-efficient office development when using EDGE. EDGE ensures that new existing office development can be designed efficiently with the lowest amount of carbon emissions possible (EDGE, 2021). A QS can create a project on the EDGE application based on the current designs and enter the required data to determine if the development will meet the EDGE certification standards of 20% savings on energy, water, and materials. Once the design meets the requirements, the project can be submitted for certification by GBCSA. This certification can be used to declare carbon emission savings when submitting carbon tax documents to SARS to qualify for the applicable rebates, resulting in less carbon tax payable.

A case study was conducted to compare the carbon tax when developing the following:

- Scenario A: An office building with a standard design;
- Scenario B: An office building using a carbon-efficient office building model.

Before determining the carbon tax for both scenarios, carbon emissions must be determined using the EDGE application. As stated in the literature review, the following steps must be taken when using this application (IFC, 2022):

1. In the application, the office building type needs to be selected;
2. The location data needs to be entered by selecting the country and city the project will commence;
3. Enter the building data, stating whether it is an open plan building, the gross building area, number of floors, hours operational and occupation density;
4. Enter the area details and office dimensions as accurately as possible to produce correct results;
5. Enter the orientation of the building;
6. When the inputs on the Design tab are entered, the following step is to select methods to save energy.

SSQS Trading (Pty) Ltd was asked if they could supply drawings of a standard office building project to test the scenarios. On 14 March 2023, SSQS Trading (Pty) Ltd granted permission to be part of the research and sent a set of drawings. For anonymity, the details of the project are not disclosed. Therefore, the project name will be Brooklyn — Office X.

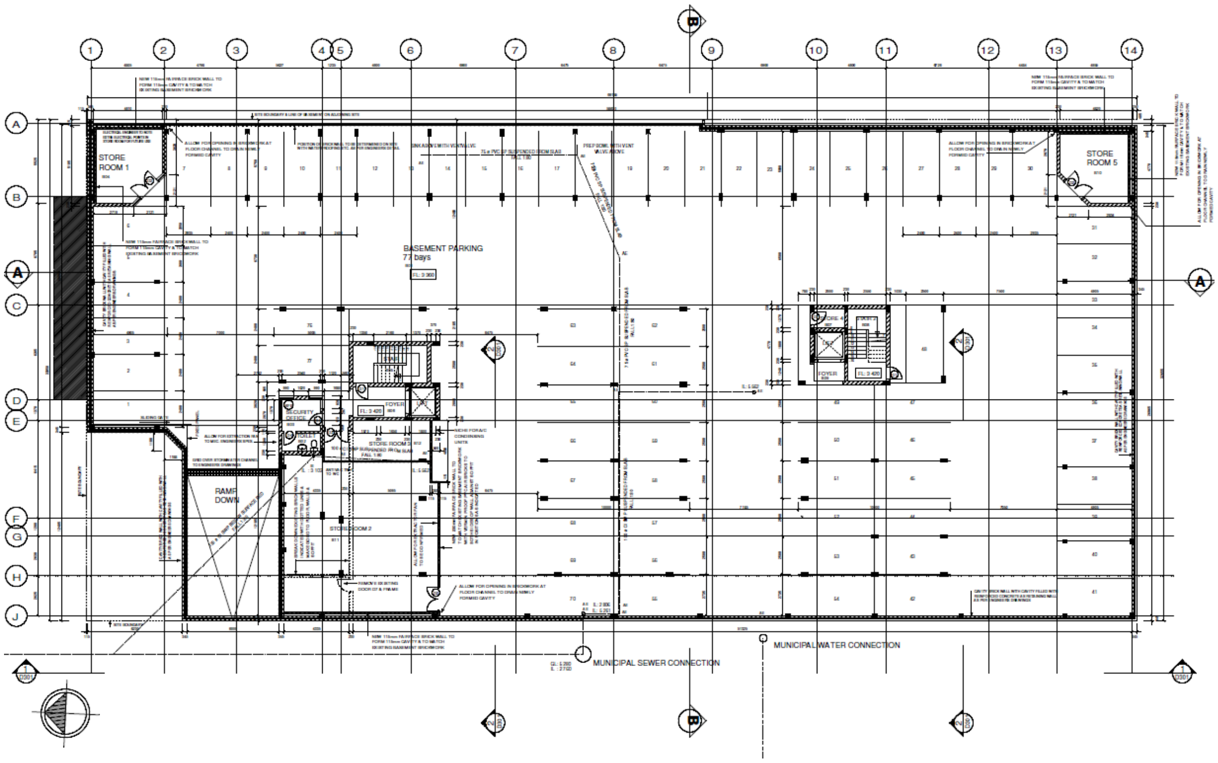

Figure 4.13: Basement of Office X

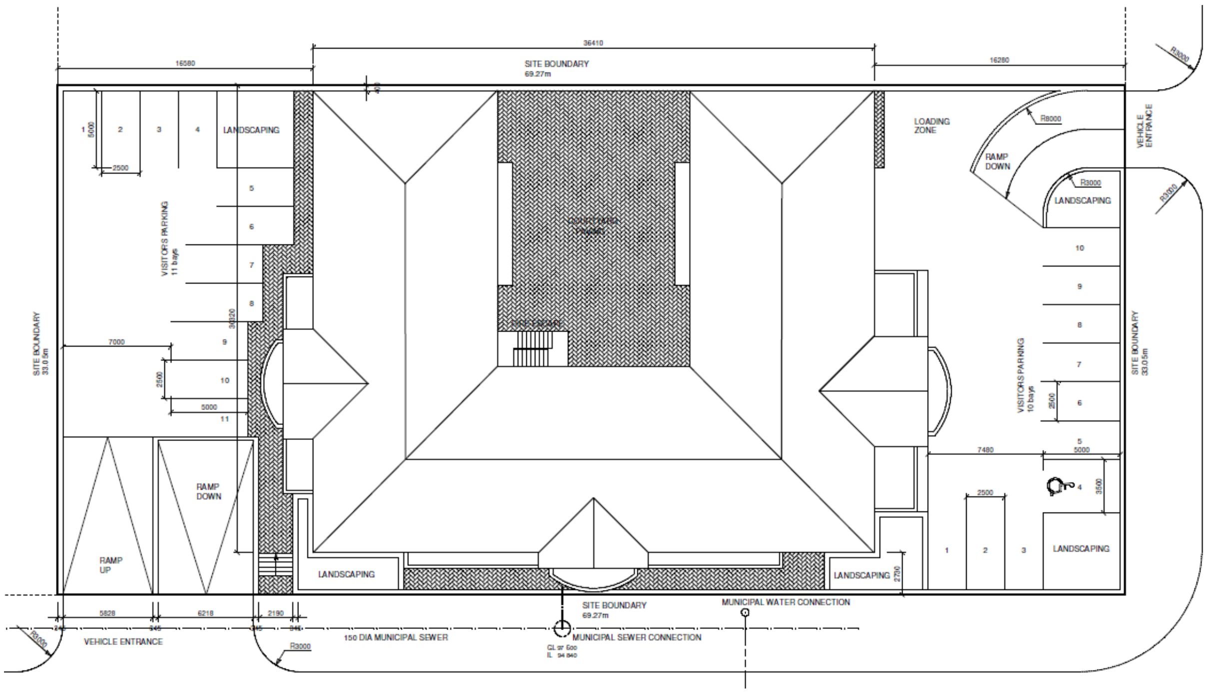

Figure 4.14: Site plan of Office X

The design section on the EDGE application for both scenarios will remain the same to compare the data. Therefore, Steps 1–5 are identical. Office X is based in Brooklyn, Pretoria, and consists of three floors above grade and one floor below grade.

The Gross Building Area (GBA) of Office X is 2 728 m^2 (excluding the basement of 2 172 m^2) with a floor to soffit height of 2.5 m high. The average occupation density of Office X was 12 m^2/person, operating 11 h/day for five working days.

The building comprises the following areas.

1. Open plan offices	:	1 846	m^2
2. Closed offices	:	225	m^2
3. Passages	:	121	m^2
4. Boardrooms	:	155	m^2
5. Lobby	:	80	m^2
6. Bathrooms	:	144	m^2
7. Storerooms	:	157	m^2
Total GBA	**:**	**2 728**	**m^2**

Figure 4.15 indicates the percentages of each building area.

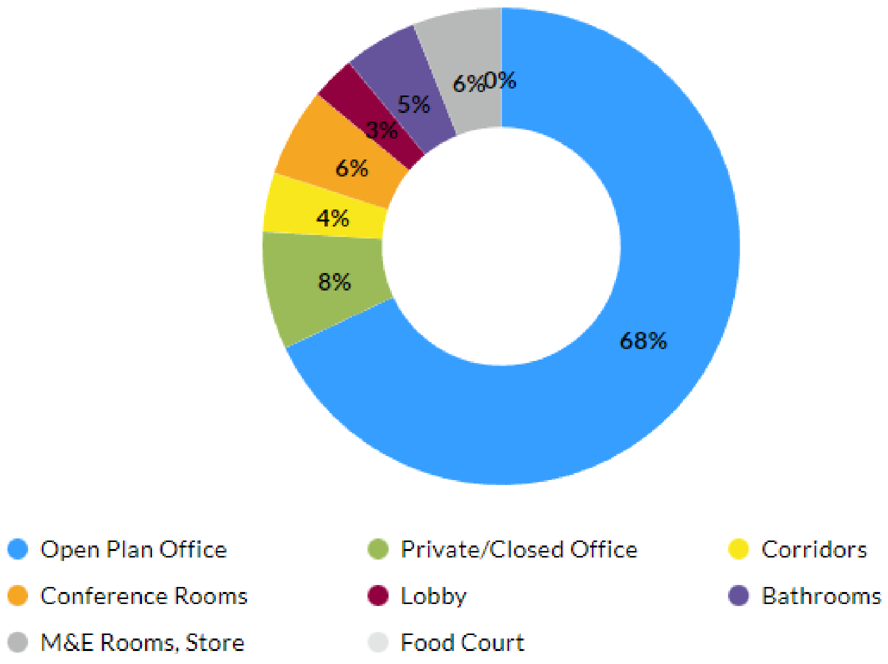

Figure 4.15: Building area breakdown (EDGE, 2023b)

The building orientation lengths are measured as follows:

1. North : 29.92 m
2. South : 29.92 m
3. East : 37.77 m
4. West : 37.77 m
5. Northeast : 17.96 m
6. Southeast : 17.96 m

The building design included an air conditioning system. Electricity supplied via Eskom as the main energy supplier, but a diesel generator is used as backup power during power failures or load shedding.

4.3.3 Scenario A: Standard Office Building Design

For Scenario A, the current building design of Office X was used and entered into the EDGE application to create a baseline for comparing Scenario B with. The three departments in which specifications and data are entered are Energy, Water, and Materials. Each department requires a minimum carbon emission reduction of 20% for certification.

4.3.2.1.1. Energy

Table 4.19: Data and specifications for energy were inserted into the EDGE application

	<u>Window to wall ratio total</u>		**20.32%**
1.1	North	:	32%
1.2	East	:	8%
1.3	Northeast	:	14%
1.4	Southeast	:	17%
1.5	South	:	21%
1.6	West	:	19%
	<u>Shading Elements</u>		
2	External shading elements	:	*Not Applicable*
	<u>Reflective Coatings</u>		
3	External roof with reflective coatings – *Concrete/Clay roof tiles*	:	SR of 0.17
4	External walls with reflective coatings – *Red clay bricks*	:	SR of 0.36
	<u>Insulation</u>		
5	Insulation to the roof – *95mm thick Mineral Wool insulation*	:	0.45 $W/m^2.K$
6	Insulation to the external walls	:	*Not Applicable*

	Glazing		
7	High thermal performance glazing – 6*mm thick bronze glazing*	:	3.83 $W/m^2.K$ with 0.45 SHGC
	Cooling Systems		
8	Air-conditioning with air cooled screw chiller	:	3.51 COP
	Energy-saving lighting		
9	External and internal areas consisting of energy-saving lighting	:	*Not Applicable*
10	Staircases and passages have lighting controls	:	*Not Applicable*
11	Open plan offices, bathrooms and conference rooms have occupancy sensors	:	*Not Applicable*
	Electricity meters		
12	Smart electricity meters	:	*Not Applicable*
	Solar PVs		
13	Solar PVs	:	*Not Applicable*
	Heated water generation *(Optional)*		
14	Spacing has a High Efficiency Condensing Boiler	:	*Not Applicable*
15	Heat pump water generation system	:	*Not Applicable*
	Offsite Renewable Energy Procurement *(Optional)*		
16	Offsite Renewable Energy Procurement	:	*Not Applicable*

Abbreviation: photovoltaics (PVs)

The above data and specifications of the building calculate an energy savings of 34.85 %, which is ideal as it exceeds the minimum requirement of 20 % to be certified. The base case for the EDGE application is 20% which is about 167 kWh/m2 per year (Figure 4.16), and Scenario A generates 110 kWh/m2 per year owing to savings based on the design.

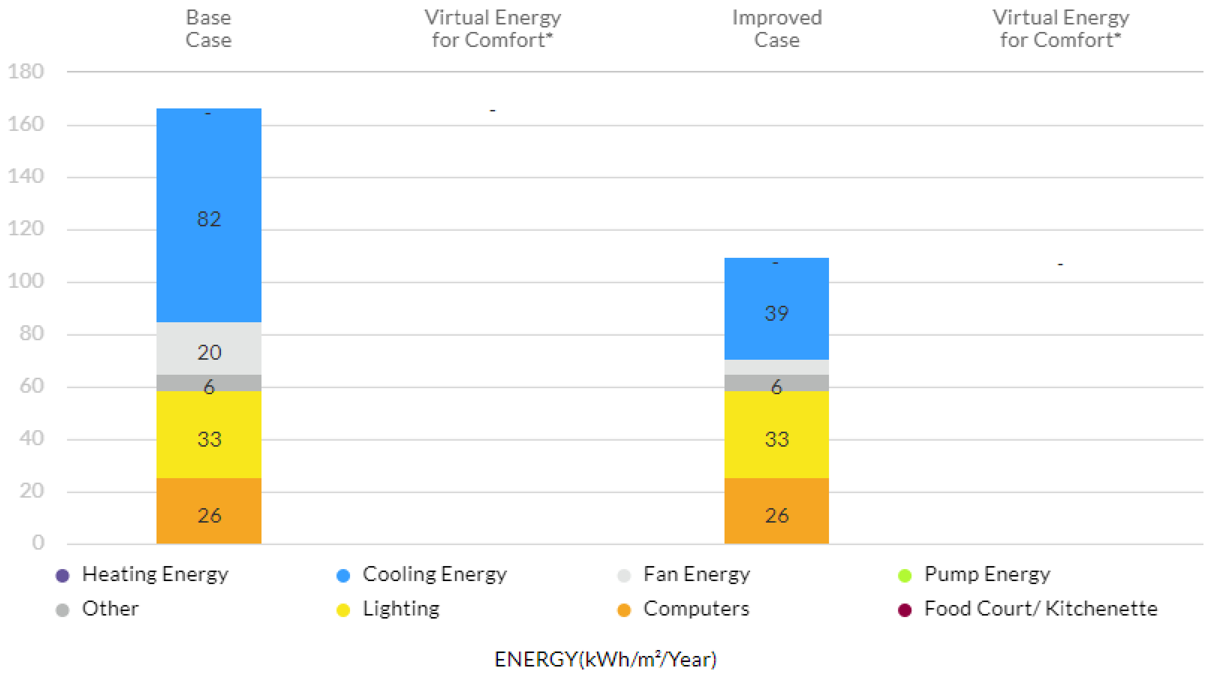

Figure 4.16: Energy savings of Office X compared to base case (EDGE, 2023b)

4.3.2.1.2. Water

Table 4.20: Data and specifications for water were inserted into the EDGE application:

	<u>**Effective water flush systems**</u>		
1	Faucets in bathrooms	:	7 L/min
2	Urinals	:	2.5 L/flush
3	Water closets — *Single flush systems*	:	11 L/flush
	<u>**Faucets and aerators**</u>		
4	Kitchen sinks faucets	:	7 L/min
	<u>**Water recovery systems**</u>		
5	Rainwater harvesting system	:	*Not Applicable*
6	Grey water treatment and recycling system	:	*Not Applicable*
7	Black water treatment and recycling system	:	*Not Applicable*
	<u>**Sundry water saving elements**</u>		
8	Smart water meters	:	*Not Applicable*

The above data and specifications of the building are calculated to be -14.83% savings, which is not ideal because it is negative and does not exceed the 20% minimum requirement to be certified. The base case for the EDGE application is 20% which is about 50 L/day per person (Figure 4.17), Scenario A generates 58 L/day per person owing to the inadequate design that does not meet the requirements.

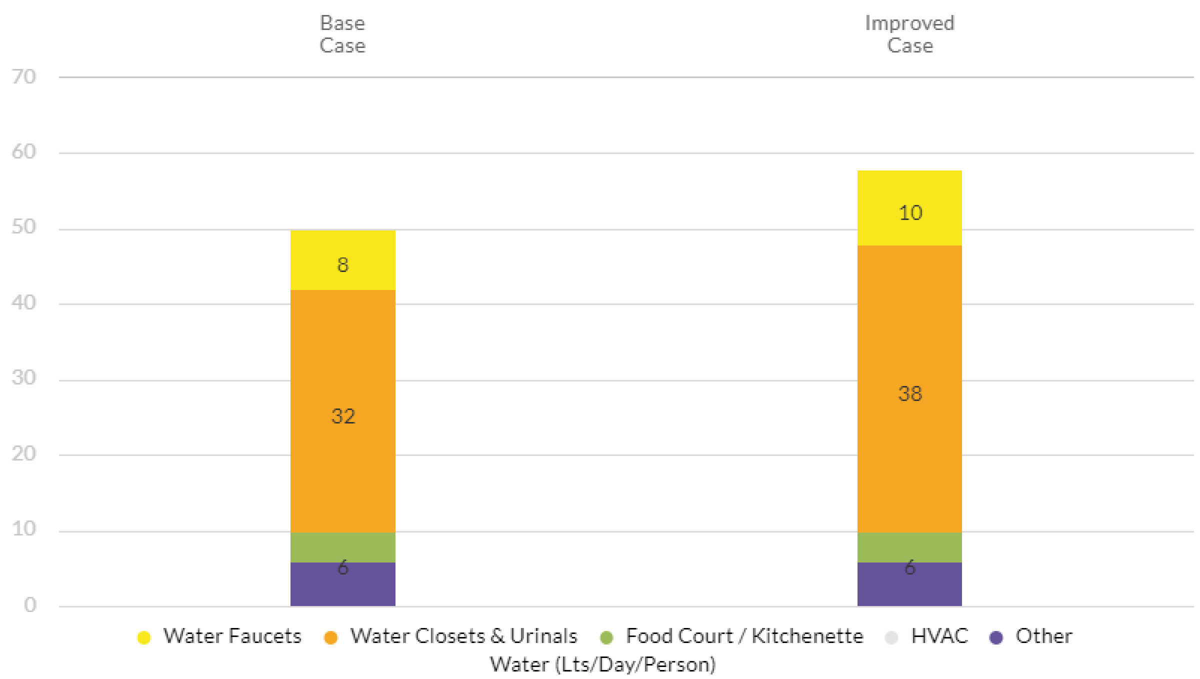

Figure 4.17: Water savings of Office X compared to base case (EDGE, 2023b)

4.3.3.1.1 Materials

Table 4.21: Data and specifications for materials inserted into the EDGE application

	<u>Floor structure</u>		
1	In-situ reinforced concrete slab – *200mm thick*	:	With steel rebar of $25kg/m^2$
	<u>Roof structure and covering</u>		
2	Clay roofing tiles on timber rafters	:	100% proportion
	<u>Internal and external walls</u>		
	Internal walls		
3	*Partitioning (Plasterboards on metal studs)*	:	80% proportion
	External walls *(Optional)*		
4	Certain walls consisting of aluminium profile cladding	:	*Not Applicable*
	Internal and external loadbearing walls		
5.1	External walls – *Exposed brick wall with internal plaster*	:	100% proportion
5.2	Internal walls – Common brick wall with plaster on both sides – *230mm thick*	:	20% proportion
	<u>Insulation in walls and roof</u>		
6	Insulation in walls	:	*Not Applicable*
7	Insulation in roof – *Glass wool*	:	125mm thick

	<u>Floor covering</u>		
8	Nylon carpets	:	82% proportion
9	Ceramic tiles	:	18% proportion
	<u>Windows</u>		
10	Aluminium window frames – *Single glazing*	:	100% proportion

The above data and specifications of the building calculate a savings of 8.94%, which is not ideal, as it does not exceed the 20% minimum requirement to be certified. The base case on the EDGE application is 20% which is about 2 676 Megajoule (MJ)/m2 (Figure 4.18), and Scenario A generates 2 437 Megajoule (MJ)/m2 owing to the inadequate design that does not meet the requirements.

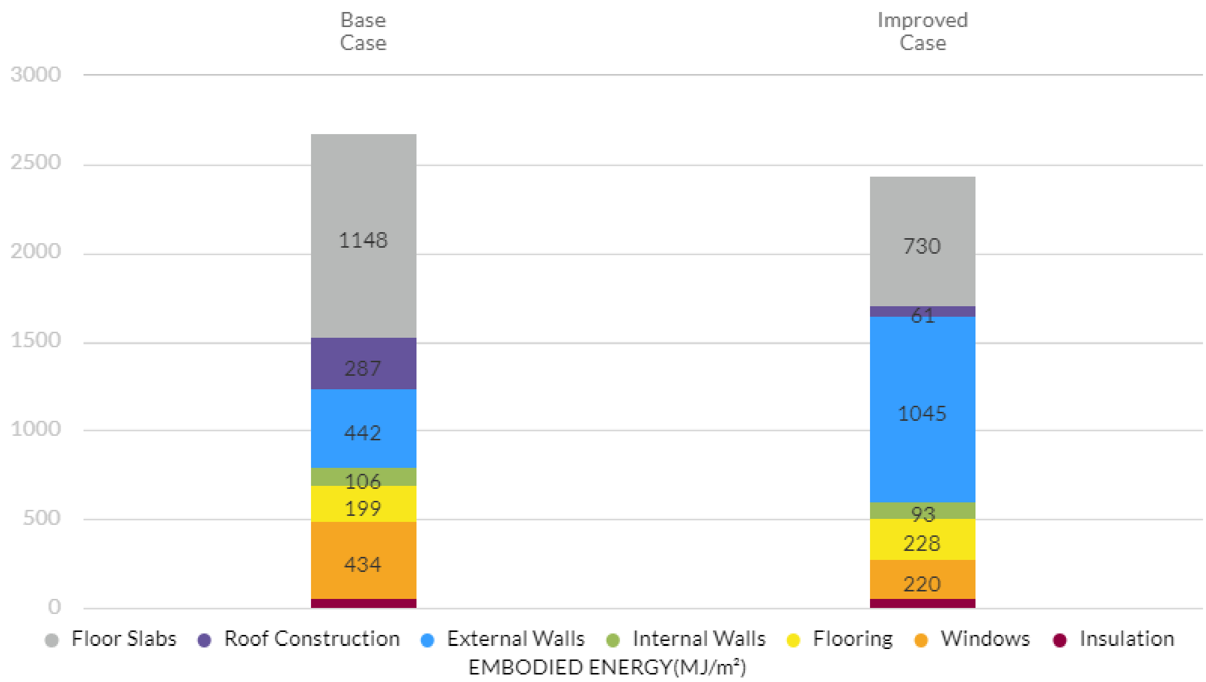

Figure 4.18: Material savings of Office X compared to base case (EDGE, 2023b)

EDGE (2023) calculated the following results based on the data and specifications of Scenario A:

1.	Final energy use	:	24 633.19	kWh per month
2.	Final water use	:	390.79	m^3 per month
3.	Carbon emissions	:	252.40	tCO_2 per year
4.	Operational carbon emission savings	:	138.40	tCO_2 per year

The total carbon emissions for Scenario A are 252.40 tCO2 per year that will be used to calculate the annual carbon tax the developer/ property owner will need to pay. For comparison purposes, tax-free allowances were not deducted from carbon emissions. As described in the literature review, the carbon tax will be ZAR 120 per 1 000 kg of carbon emissions, which is above the tax-free threshold. Section 5 of the Carbon Tax Bill indicates that there will be an increase in the tax rate per year by the rate of consumer price inflation (CPI) plus 2% until 31 December 2022 and the adjustments will be in accordance with inflation from 2023 (National Treasury, 2018). McKenzie (2023) stated that the current annual carbon tax rate for 2022 is ZAR 144 per tCO2. The annual CPI for 2023 (7.1%) must be considered (Stats, SA, 2023). Therefore, the annual tax rate for 2024 is ZAR 190 per tCO2.

Carbon Tax can be calculated:

Tax base = Total quantity of GHG emissions minus tax-free allowances (if any).

Carbon tax **=** ***Tax base x Rate of carbon tax***

= ***252.40 x 190***

= ***47 956.00***

Therefore, the annual carbon tax the developer/ property owner will need to pay SARS is ZAR 47,956.00.

Scenario B: Office building designed with the Carbon Efficient Office Building Model

For Scenario B, the same building dimensions of Office X were used, but data and specifications from the SA Carbon Efficient office building model (Table 4.18) were entered into the three departments: Energy, Water and Materials.

4.3.2.2. Energy

Table 4.22: Data and specifications for energy inserted into the EDGE application

	Window to wall ratio total		**21.72%**
1.1	North	:	40%
1.2	East	:	15%
1.3	Northeast	:	15%
1.4	Southeast	:	10%
1.5	South	:	21%
1.6	West	:	15%
	Shading Elements		

2	External shading elements	:	*0.48*
	Reflective Coatings		
3	External roof with reflective coatings – *Concrete roof tiles with white coating*	:	SR of 0.9
4	External walls with reflective coatings – *Bricks painted with Stone coloured coating*	:	SR of 0.62
	Insulation		
5	Insulation to the roof – *95mm thick Mineral Wool insulation*	:	0.45 $W/m^2.K$
6	Insulation to the external walls	:	*Not Applicable*
	Glazing		
7	High thermal performance glazing – 8*mm thick grey glazing*	:	3.24 $W/m^2.K$ with 0.32 SHGC
	Cooling Systems		
8	VRF with a groundwater source < 40 kW	:	4.75 COP
	Energy-saving lighting		
9	External and internal areas consisting of energy-saving lighting	:	Yes
10	Staircases and passages have lighting controls	:	Yes
11	Open plan offices, bathrooms and conference rooms have occupancy sensors	:	Yes
	Electricity meters		
12	Smart electricity meters	:	Yes
	Solar PVs		
13	Solar PVs – *25% of annual electricity use*	:	Yes
	Heated water generation *(Optional)*		
14	Spacing has a High Efficiency Condensing Boiler	:	*Not Applicable*
15	Heat pump water generation system	:	*Not Applicable*
	Offsite Renewable Energy Procurement *(Optional)*		
16	Offsite Renewable Energy Procurement	:	*Not Applicable*

Abbreviation: photovoltaics (PVs)

The above data and specifications of the building calculate energy savings of 69.47%, which is ideal because it exceeds the minimum requirement of 20 % to be certified. The base case for the EDGE application is 20% which is about 167 kWh/m2 per year (Figure 4.19), and Scenario B generates 51 kWh/m2 per year owing to the savings based on the design.

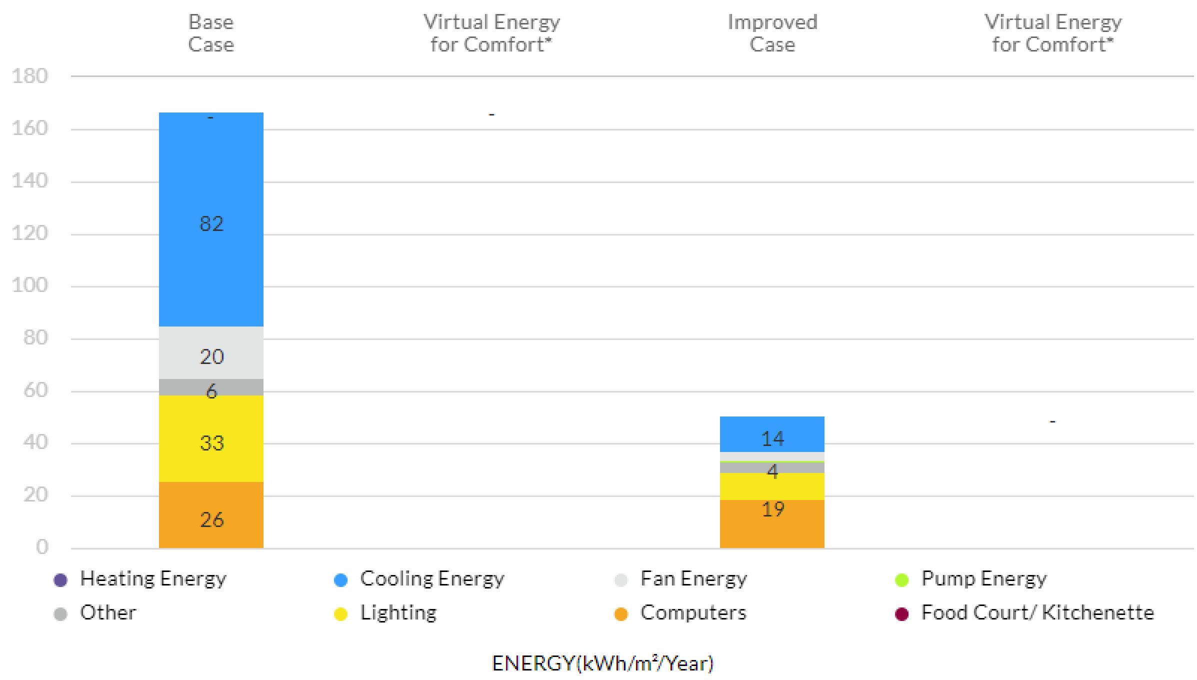

Figure 4.19: Energy savings of Office X compared to base case (EDGE, 2023b)

4.3.3.1.2 Water

The following data and specifications were inserted into the EDGE application.

Table 4.23: The following data and specifications were inserted into the EDGE application

	Effective water flush systems		
1	Faucets in bathrooms	:	2 L/min
2	Urinals	:	2 L/flush
3	Water closets — *Dual flush systems*	:	6 L/flush high-volume flush and 3 L/flush low-volume flush
	Faucets and aerators		
4	Kitchen sinks faucets	:	6 L/min
	Water recovery systems		
5	Rainwater harvesting system	:	Yes
6	Grey water treatment and recycling system	:	Yes
7	Black water treatment and recycling system	:	Yes
	Sundry water saving elements		
8	Smart water meters	:	*Not Applicable*

The above data and specifications of the building calculate savings of 79.26%, which is ideal as it exceeds the minimum requirement of 20 % to be certified.

The base case for the EDGE application is 20% which is about 50 L/day per person (Figure 4.20), and Scenario B generates 11 L/day per person owing to the savings based on the design.

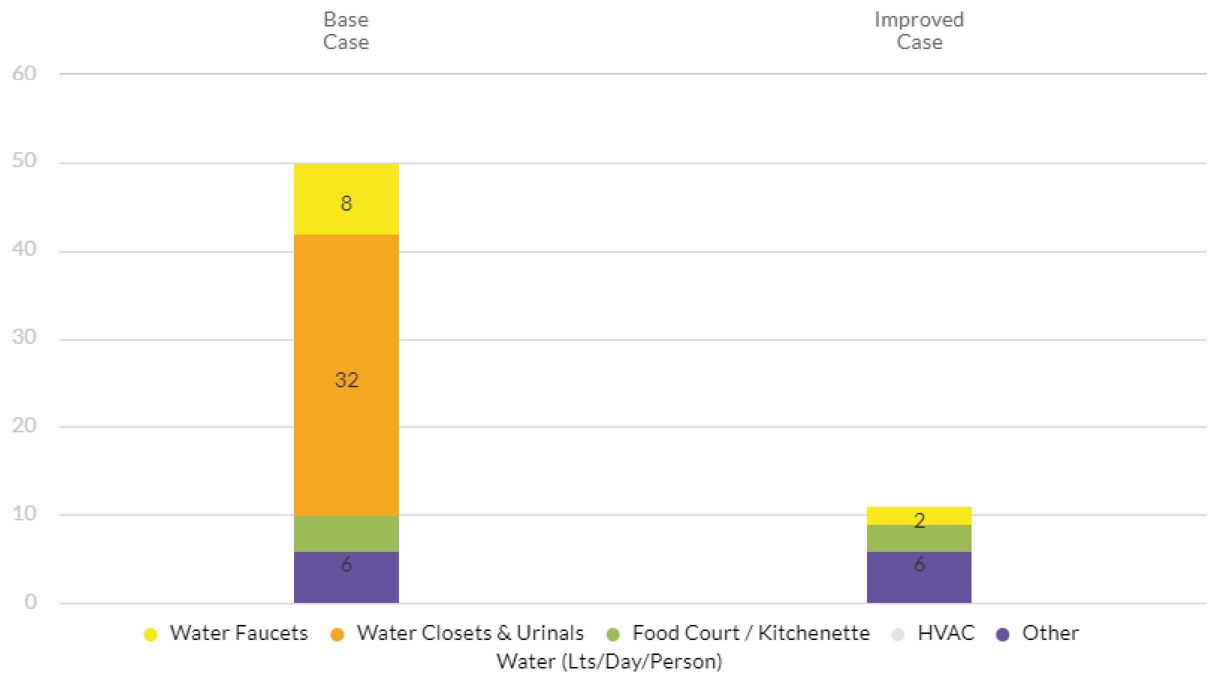

Figure 4.20: Water savings of Office X compared to base case (EDGE, 2023b)

4.3.3.1.3 Materials

The following data and specifications were inserted into the EDGE application.

Table 4.24: The following data and specifications were inserted into the EDGE application.

	Floor structure		
1	In-situ reinforced concrete with more than 30% PFA – *200mm thick*	:	With steel rebar of 25kg/m^2
	Roof structure and covering		
2.1	In-situ reinforced concrete with more than 30% PFA – *200mm thick* *(For the rainwater harvesting system a concrete roof space might be required)*	:	With steel rebar of 25kg/m^2 50% proportion
2.2	Clay roofing tiles on timber rafters	:	50% proportion
	Internal and external walls		
	Internal walls		
3	*Partitioning (Plasterboards on metal studs)*	:	80% proportion
	External walls *(Optional)*		
4	Certain walls consisting of aluminium profile cladding	:	*Not Applicable*
	Internal and external loadbearing walls		

5.1	External walls – *Autoclaved aerated concrete blocks – 220mm thick*	:	100% proportion
5.2	Internal walls – *Autoclaved aerated concrete blocks – 150mm thick*	:	20% proportion
	Insulation in walls and roof		
6	Insulation in walls	:	*Not Applicable*
7	Insulation in roof – *Glass wool*	:	60mm thick
	Floor covering		
8	Finished concrete floor	:	100% proportion
	Windows		
9	Aluminium window frames – *Single glazing*	:	100% proportion

The above data and specifications of the building calculate a savings of 49.09 %, which is ideal because it exceeds the 20% minimum requirement to be certified. The base case for the EDGE application is 20% which is about 2 676 Megajoule (MJ)/m2 (Figure 4.21), and Scenario B generates 1 363 Megajoule (MJ)/m2 due to the savings based on the design.

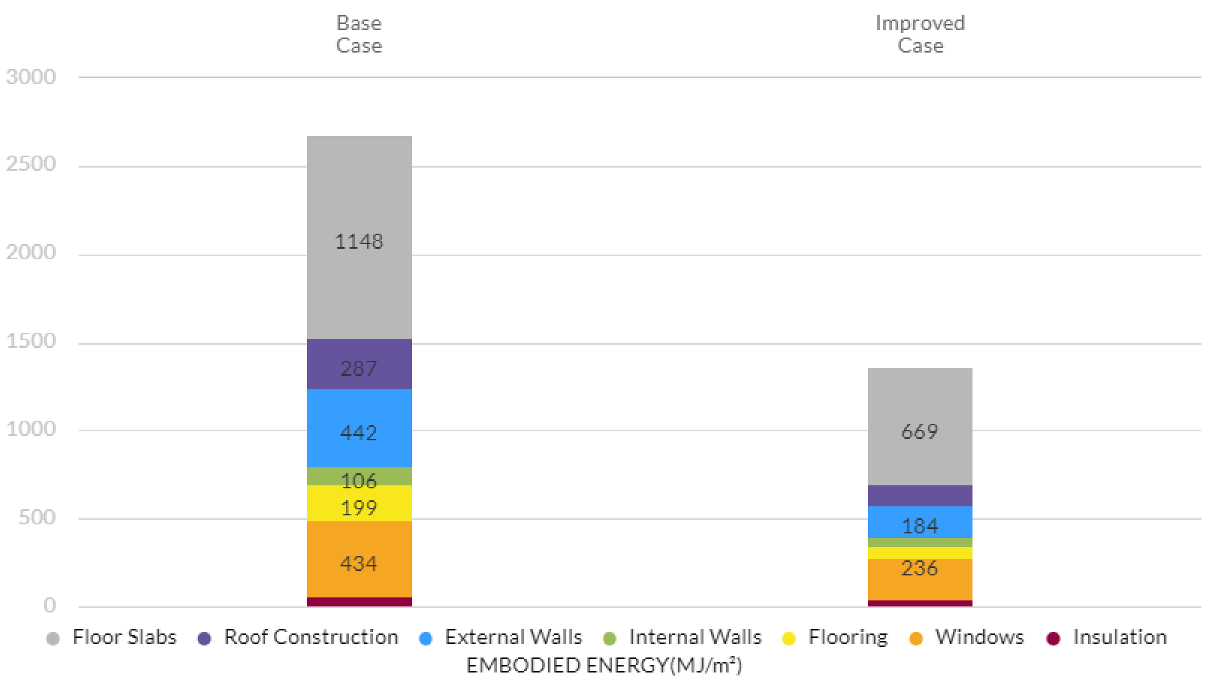

Figure 4.21: Material savings of Office X compared to base case (EDGE, 2023b)

EDGE (2023) calculated the following results based on the data and specifications of Scenario B:

1.	Final energy use	:	11 646.72	kWh per month
2.	Final water use	:	70.59	m^3 per month
3.	Carbon emissions	:	119.40	tCO_2 per year

4. Operational carbon emission savings : 271.45 tCO_2 per year

The total carbon emissions for Scenario B are 119.4 tCO_2 per year that will be used to calculate the annual carbon tax the developer/ property owner will need to pay. For the purposes of comparison, tax-free allowances are not deducted from the carbon emissions.

Carbon Tax can be calculated:

Tax base = The total quantity of GHG emissions minus tax-free allowances (if any).

Carbon tax* = *Tax base x Rate of carbon tax
= *119.40 x 190*
= *22 686.00*

Therefore, the annual carbon tax the developer/ property owner will need to pay SARS is ZAR 22,686.00.

4.3.3.2 Comparison Between Scenario A and B

In comparing Scenario A with Scenario B, Scenario B has more favourable results than Scenario A. Table 4.25 shows that Scenario B offers more energy and water savings, as well as more operational carbon emission savings. Scenario A had a final energy use of 24 633.19 kWh per month, and Scenario B had 11 646.72 kWh per month, saving 12 986.47 kWh per month. Scenario A has a final water use of 390.79 m3 per month, and Scenario B has 70.59 m3 per month, saving 320.20 m3 per month. Scenario A has operational carbon emissions saving of 138.40 tCO2 per year and Scenario B has operational carbon emissions 271.45 tCO2 per year, giving additional savings of 133.05 tCO2 per year.

Table 4.25: Results from Scenario A and Scenario B

	Scenario A	**Scenario B**	
1. Final energy use	24 633.19	11 646.72	kWh per month
2. Final water use	390.79	70.59	m^3 per month
3. Carbon emissions	252.40	119.40	tCO_2 per year
4. Operational carbon emission savings	138.40	271.45	tCO_2 per year
Annual carbon tax	**R 47 956.00**	**R 22 686.00**	**Per year**

Scenario A's office building emits 252.40 tCO_2 per year which means that the developer/ property owner will need to pay an ZAR 47,956.00 carbon tax per year. Scenario B's office building emits 119.40 tCO_2 per year which means that the developer/ property owner will need to pay an ZAR 22,686.00 carbon tax per year. There is a saving of ZAR 25,270.00 that does not need to be paid to SARS should the developer/ property owner decide to develop the building based on Scenario B. Therefore, the SA Carbon Efficient office building model will reduce the influence of carbon tax on the developer/ property owner.

When cumulative savings across multiple buildings are considered, even relatively small individual savings can be added to developers with a considerable commercial building portfolio. A typical saving of ZAR 25,270.00 per building results in a total saving of ZAR 126,350.00 for five buildings of the same type and size. This reveals how the benefits of adopting the carbon-efficient office building model become more evident as the scale of the commercial building portfolio increases. For developers with a substantial number of commercial buildings in their portfolios, potential savings could be even more significant. The carbon-efficient office building model designed in this research, which optimises energy efficiency and operational costs, can contribute to long-term cost savings for developers by lowering operational expenses, maintenance costs, and other utility expenditures.

Furthermore, apart from direct financial savings, adopting sustainable practices and an energy-efficient building model can improve the overall market value of buildings and attract environmentally conscious tenants. This can lead to higher occupancy rates, improved tenant satisfaction, and potentially, higher rental income. It is important for developers to consider the long-term financial benefits and environmental impact. By taking a holistic approach and considering the cumulative savings across portfolios, developers can make informed decisions that align with their financial and sustainability goals.

A net zero-carbon building can be certified when the onsite energy savings are more than 40% compared to the base case building and when the operational emissions offset is 100% (EDGE, 2023b). This model is ideal to be considered as a net zero-carbon model when solar PVs are used to generate 100% electricity (and excess electricity is fed back into the grid) and efficient water use for savings in water consumption. As identified in the literature, the Vodafone SSIC is a perfect example in SA to follow, and relates to the office building model, where sufficient energy is generated for building operations that can feed the remaining energy into the grid, grey water is reused for irrigation and toilet flushing, energy-efficient lighting is used, concrete comprises 60% cement alternatives, 60% steel is reused, and there is a waste management and recycling system in place.

Therefore, the office building model is an ideal guideline when designing a new commercial building project or refurbishing an existing commercial building.

4.3.4 Questionnaire: Data Obtained From Respondents

Response Rate to Questionnaire Sent Out Electronically

Of the 17 developers contacted, all responses and non-responses were collected and formed a part of the data analysis. Figure 4.22 shows that 59% of respondents responded telephonically or electronically to the questionnaire. It was communicated that participation was voluntary and that respondents could withdraw at any time without penalty; 6% of respondents responded that they would like to participate but did not respond to further correspondence. Therefore, it was noted that respondents withdrew from participation. Because participation was voluntary, 35% of the developers did not respond telephonically and electronically despite numerous follow-ups. Therefore, these respondents chose not to participate in the study.

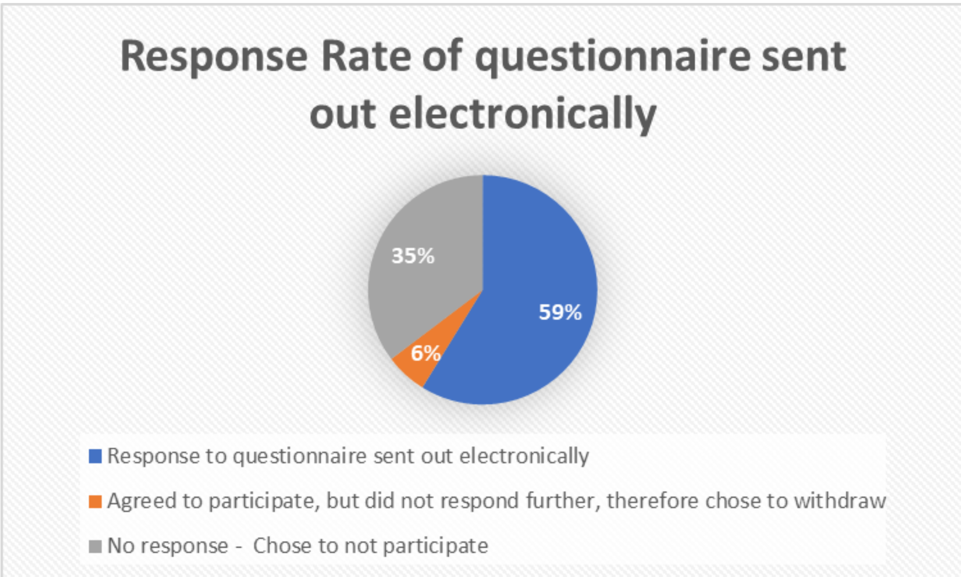

Figure 4.22: Response Rate Pie Chart

As noted in the literature review, Mishra and Isazada (2021) state that change cannot be avoided in today's world of uncertainty, complexity, ambiguity, and instability. The problem lies when change initiatives are met with resistance by companies. When companies are content in their current state of operation, the probability of resistance is higher. Change involves many unknowns, and causes anxiety, fear, ignorance, and bias, leading to resistance. Familiarity is a comfort zone where some companies prefer to be, as they fear the unknown, increasing the likelihood of sabotaging or ignoring the reasons for change.

NSF Consulting (2024) added that some respondents may be reluctant to disclose information or feel unwilling to disclose sensitive information, as it may cause embarrassment or threaten their company image. Some developers have disclosed that the carbon tax is classified as a sensitive topic. Additional reasons why some developers chose not to participate are that they may be ignorant of the topic, they were not interested, they were too busy, or they ignored correspondence.

Question 1: Do you have buildings that are green stars rated or constructed from sustainable materials?

Of the 17 respondents:

- Three indicated that they had green star-rated or sustainably constructed commercial buildings in their portfolio;
- Six respondents indicated the absence of green star-rated or sustainably constructed commercial buildings;
- Some of these respondents mentioned reasons such as adherence to conventional construction methods, limited knowledge about carbon-neutral buildings, and carbon tax, making it difficult to respond to certain questions;
- Some respondents are embarking on investigations into carbon-neutral buildings, or they lack clearance from their human resources (HR) department to answer the question;
- One respondent expressed a desire to participate electronically, but did not respond to any communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.26: Responses received for Question 1

	Responses received	Number of responses
Response 1	Yes, we were involved in the Aurecon building in Lynwood bridge	1
Response 2	No, currently we have no green-star rated buildings	1
Response 3	Yes, we currently have 160 Green Star ratings within our portfolio covering commercial, retail and industrial properties. Further details can be found in our ESG report published on our website	1
Response 4	Yes, we have several green star rated buildings (GBCSA, LEAD, EDGE). We focus on our material choices, water harvesting, water filtration, grey water systems, water efficienct systems, solar, LED lighting, façade ratios for light and heat and smart glass	1
Response 5	No, We don't have any green star rated buildings in our portfolio at the moment. We only use conventional building material to construct our buildings without any focus on sustainable materials to be honest. The reasons for this are lack of knowledge, the time and cost involved in changing from our conventional way of of building which suits our model and is optimized in a way with the entire consultant and contractor team, and the availability of materials. We develop in rural areas across the country so we try and source as much of the material as possible from local sources and distributers.	1
Response 6	No, Currently not in a position to make any formal comment on this	1
Response 7	No, we cannot answer as we know little about the subject and currently we don't have any green star rated buildings in our portfolio	1
Response 8	No, we cannot answer as we know little about the subject and currently we don't have any green star rated buildings in our portfolio	1
Response 9	No, we cannot answer as we only starting to investigate carbon neutral buildings now and currently we don't have any green star rated buildings in our portfolio	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that a greater number of developers (small-to medium-sized developers) lack green star-rated or sustainably constructed commercial buildings in their portfolio compared to those who do (large-sized developers). This trend appears to originate from a lack of knowledge regarding sustainable development or repeated reliance on conventional building methods among developers.

Question 2: Are you aware that South Africa has committed to having all existing buildings operate at Net Zero by 2050 and new buildings by 2030? If yes, please specify the actions you have taken.

Of the 17 respondents:

- Five respondents responded that they are aware of the commitments that SA has made to operate at net zero;
- Four respondents indicated that they were not aware of these commitments; they had limited knowledge about carbon-neutral buildings and carbon taxes, making it difficult to respond to certain questions;

- Some respondents are just embarking on investigations into carbon-neutral buildings, or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.27: Responses received for Question 2

	Responses received	Number of responses
Response 1	Yes, we debate this with clients on a regular basis	1
Response 2	Yes, we are aware of the target. At this point we have not analyzed the requirements or considered possible interventions	1
Response 3	Yes, we are well aware of this, and have our own commitments which are detailed in our ESG report. We are also formally committed to the UN Global Compact and align our strategy with the UN Sustainable Development Goals. Full detials of our commitments to all new buildings being Net Zero by 2035 are detailed in our ESG report, and we are algined to our buildings being net zero by 2050. We also currently have three Net Zero Carbon buildings within our portfolio	1
Response 4	Yes, we already design as per current green principals	1
Response 5	Yes, I am aware, but most people in our Company has not bought into the idea yet. The actions we have taken, which mainly focusses on our electrical usage and the installation of PV panels, is because we are forced by current conditions like loadshedding and water shortages instead of an actual drive for sustainability.	1
Response 6	No, Currently not in a position to make any formal comment on this	1
Response 7	No, we cannot answer as we know little about the subject and currently we don't know about these commitments	1
Response 8	No, we cannot answer as we know little about the subject and currently we don't know about these commitments	1
Response 9	No, we cannot answer as we only starting to investigate carbon neutral buildings now.	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that a greater number of developers (large-size developers) are aware of SA's commitments to have all existing buildings operate at Net Zero by 2050 and new buildings by 2030 because of their international involvement in green building methods and sustainable building methods compared to those who do not (small-to medium-sized developers). This trend of some small to medium-sized developers appears to originate from a lack of knowledge about sustainable development, lack of investigation into carbon neutral buildings or a repeated reliance on conventional building methods among these developers.

Question 3: Are you committed that your buildings have a minimal impact on the environment, to proactively reduce and control their carbon emission footprint from a truthful baseline, as well as to reduce the carbon footprint of your buildings?

Of the 17 respondents:

- Five respondents responded that they are committed to reduce their impact by way of energy efficiency, carrying out a Carbon Footprint Assessment annually, obtain a financial benefit, reduced mechanical installations and water savings;
- Four respondents indicated that they cannot answer as they do not know what the commitment toward carbon-neutral buildings entail, some respondents are just embarking on investigations into carbon-neutral buildings, or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.28: Responses received for Question 3

	Responses received	Number of responses
Response 1	Yes, but affordability in an depressed economy does hamper the progress to achieve	1
Response 2	At this point we only implement “green” items in our building that is either legislated (building regulations) or has a positive financial benefit (or both). We do however subscribe to the concept that all industries need to be as energy efficient as possible and reduce carbon emissions. This process must, however, take into account economic conditions and industry role players must be consulted.	1
Response 3	Yes, we are. We do an annual Carbon Footprint Assessment which is publically available on our website and we follow the GHG Protocol	1
Response 4	Yes, it makes business sense. Additional initial CAPEX is recoved through long term saving by having efficient (green) buildings	1
Response 5	In the current economic climate we are mostly focused on the economical efficiency of our buildings. This does help a bit with our design and specification process where we try and use energy efficient systems and installations like more natural light, LED lights, natural ventilation instead of mechanical systems, etc. Most of our consumption costs are recovered from tenants however, so the efficiency of tenant installations does not really concern us. With our solar installations we manage to reduce for example the size of our Eskom or Municipal electrical connections because we can supplement the shortfall with alternative sources, but that also comes from a cost saving point of view rather than an environmental impact approach. We do however try and minimize our environmental impact in areas like water consumption, waste production, etc.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about the subject and what this commitment entails	1
Response 8	We cannot answer as we know little about the subject and what this commitment entails	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that a greater number of developers (large size developers) are committed to reduce their impact by way of energy efficiency, carrying out a Carbon Footprint Assessment annually, obtain a financial benefit, reduced mechanical installations and water savings compared to medium-sized developers that do not know what this commitment entails or could not answer the question.

Question 4: Are you up to date with the current events taking place by the GBCSA?

Of the 17 respondents:

- One respondent responded that they are up to date with current events;
- Two respondents responded that they are up to date with current events to some extent;
- Two respondents responded—that they are not up to date with current event implemented by the GBCSA;

- Four respondents indicated that they cannot answer as they do not know much about the current events taking place or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question;
- Six developers opted not to participate;

Table 4.29: Responses received for Question 4

	Responses received	Number of responses
Response 1	No	1
Response 2	We are aware of the broad principles but is not up to speed with latest developments and detail	1
Response 3	Yes, we work closely with the GBCSA, and our Chief Sustainability Officer sits on their board	1
Response 4	Mostly up to date. Could be better communicatied with us developers	1
Response 5	Not at all	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about the subject and these current events	1
Response 8	We cannot answer as we know little about the subject and these current events	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that most developers are not up to date or only up to date with the current events, indicating a gap in current sustainable and carbon efficient developments.

Question 5: Why do you believe to invest in green star-rated buildings?

Of the 17 respondents:

- Three respondents responded that they believe to invest in green star-rated buildings as there is a marketing benefit, financial benefits, attracts tenants that has their own ESG reports, and capital expenses can be recovered over the long run;
- Two respondents responded that they do not pursue to invest in green star-rated buildings besides energy saving measures that has financial benefit for the company or they focus more on sustainable water usages;
- Four respondents indicated that they cannot answer as they do not know much about the current events taking place or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;

- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.30: Responses received for Question 5

	Responses received	Number of responses
Response 1	Firstly there is a perceived marketing benefit and secondly for the environment	1
Response 2	We do not peruse green-star rated developments and only implement additional (over and above building regulations) energy saving measures that has financial benefit	1
Response 3	Besides the advantages of having Green Star properties in the portfolio, and its ability to attract and retain tenants who are on their own ESG journey, it is also heavily used in our Sustainabiltiy linked bonds and Green Bonds, so they form a strategic part of our comapny financing models	1
Response 4	It makes business sense. Additional initial CAPEX is recoved through long term saving by having efficient (green) buildings	1
Response 5	We have seen the impact of failing infrastructure and lack of service delivery, so to be honest we try and reduce our dependency on external suppliers and a lot of this does contribute to better sustainability, but it comes from the "wrong place" I guess. Water is a massive problem for us in the areas we develop, so more focus goes into water usage and wastage than anything else.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about the subject and what this commitment entails	1
Response 8	We cannot answer as we know little about the subject and what this commitment entails	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that more developers believe to invest in green star-rated buildings due to the benefits of marketing as a sustainable developer, there are financial benefits, attracts tenants that believe in sustainable development and the company's capital expenses can be recovered over the long run.

Question 6: Are you aware that South Africa has enforced carbon tax which will be applicable to your property portfolio? If yes, who made you aware of this?

Of the 17 respondents:

- Three respondents responded that they are aware that SA has enforced carbon tax that are applicable on their property portfolio through their tax advisors and auditors or keep up to date with both local and international regulations as a matter of course through their ESG and legal department;
- One respondent responded that they are aware of the carbon tax applicable, but only to some extent as they became aware of this through general news media;
- One respondent responded that they are not aware of carbon tax applicable on their property portfolio;

- Four respondents indicated that they cannot answer as they do not know much about the current events of carbon tax applicable of the property portfolio or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.31: Responses received for Question 6

	Responses received	Number of responses
Response 1	Yes, our auditors	1
Response 2	We are aware the it will be requirements some point but we are not up to speed on the details. I became aware of it through general news media	1
Response 3	Yes, we are aware of this and have had it on our radar since it was first moted and promulgated. We keep up to date with both local and international regulations as a matter of course through our ESG department and our legal department	1
Response 4	Yes, tax advisors	1
Response 5	I am not aware no. Neither is most people in my company	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that a few developers are aware of the carbon tax applicable of the property portfolio due to their auditors or tax advisors or international relationships as they are large sized developers. However, note that small to medium sized developers are less aware of the enforcement of carbon tax.

Question 7: With carbon tax coming into effect in 2023, does this worry you about having an additional tax to declare and pay?

Of the 17 respondents:

- Four respondents responded that they are concerned about the carbon tax coming into effect on their property portfolio due to financial burdens, income pressures, whether some of the buildings in their portfolio are too old to be converted to be carbon efficient or it will impact investors and shareholders' dividends;
- Five respondents indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio, they cannot comment as

it is being reviewed by their operational finance department or they lack clearance from their HR department to answer the question;

- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.32: Responses received for Question 7

	Responses received	Number of responses
Response 1	Yes, the property sector is already burdened with ever increasing costs in a scenario where income is also under pressure. Thus just a further nail in the coffin	1
Response 2	From a cost burden point of view, any additional tax is a concern as it increases operational costs. If interventions to minimize the level of carbon tax is not feasible from a financial point of view, the concept of carbon tax can become restrictive and will drive up costs	1
Response 3	We are currently not in a position to make any formal comment on this, as it is being reveiwed by our operational finance department	1
Response 4	Yes, some older buildings are not able to be converted or improved to meet latest green requirements. Do you then sell these? But at some point, it is better to keep them and refurb than to keep build new	1
Response 5	Yes it does. We are a listed Company so most of our operating info including expenses are audited and published each year. More tax would have an impact on investor and shareholder dividends so it will create concerns and questions	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that more respondents are hesitant to answer whether they are worried about declaring and paying carbon tax due to either not having permission to answer from their relevant departments or that they do not know how the carbon tax will affect their business and property portfolio. Larger size developers were more open to answering this question. It is also noted that some developers are hesitant towards answering the question, indicating that they are unfamiliar with carbon tax on buildings.

Question 8: Will you declare your building electricity use to SARS to pay for the carbon tax? Please explain why/why not.

Of the 17 respondents:

- Three respondents responded that they would declare their electricity usage where it is a requirement and to be transparent;

- One respondent responded that it will still be decided whether they would declare their electricity usage;
- Five respondents once again indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio, they cannot comment as it is being reviewed by their operational finance department or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.33: Responses received for Question 8

	Responses received	**Number of responses**
Response 1	To be decided	1
Response 2	We will declare any information that is legally required. We are aware that for certain building types, there is a process in place where property owners are required determine the energy efficiency of the buildings and display the rating in the building (EPC process) . We are in the process of finalizing the process and will comply with the requirements. We have further appointed a service provider to convert our electricity consumption to carbon consumption and have produced figures for 2023	1
Response 3	We are currently not in a position to make any formal comment on this, as it is being reveiwed by our operational finance department	1
Response 4	If it is a requirement, than yes	1
Response 5	Yes we will. As mentioned above, we are listed on the JSE and cannot afford to not be transparent in any way.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that more respondents are hesitant to answer whether they will declare their building electricity usage to SARS to pay carbon tax due to either not having permission to answer from their relevant departments or that they do not know how the carbon tax will affect their business and property portfolio. Developers with a substantial number of buildings were more open to answering this question. It is also noted that some developers are hesitant towards answering the question, indicating that they are unfamiliar with carbon tax on buildings.

Question 9: How do you think carbon tax will affect your development and maintenance of buildings?

Of the 17 respondents:

- Four respondents responded that carbon tax will negatively affect their developments and maintenance of their buildings due to the property sector already burdened with increasing expenses, less cost saving, more selective designing, increasing operating expenses and not fully understanding how carbon tax is calculated on their buildings which can delay the commencement of idea and design stage;
- Five respondents once again indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio, they cannot comment as it is being reviewed by their operational finance department or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.34: Responses received for Question 9

	Responses received	**Number of responses**
Response 1	Negative, the property sector is already burdened with ever increasing costs in a scenario where income is also under pressure. Thus just a further nail in the coffin	1
Response 2	If the intevenions to reduce emissons, does not translarte in cost saving or at least break even in terms of cost, it will result in additional expenses, which will drive costs up for the entire industry, including the end user. In the long run, legislation and cost effective solution will help to reduce the carbon footprint in the property industry.	1
Response 3	We are currently not in a position to make any formal comment on this, as it is being reveiwed by our operational finance department	1
Response 4	We will be more selective during design period to ensure long term carbon effects are taken into account	1
Response 5	We will be forced to be more sustainable from a financial point of view. The problem is that I (and we) don't fully understand how and on what the carbon tax will be calculated so it is difficult to say exactly how we will be affected. The bottom line is that any and all operating expenses has a massive impact on the overall success and financial feasibility of our developments, so the ultimate aim is to get the operating expenses down without a massive capital expenditure during the development phase.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that more respondents are hesitant to answer how carbon tax will affect their development and maintenance on their buildings. However, other respondents indicated that carbon tax would negatively impact their development and maintenance. Therefore, note that most developers are hesitant towards the benefits that carbon tax hold.

Question 10: Will you increase the rent of your tenants or add a levy to compensate the carbon tax? Please explain why.

Of the 17 respondents:

- Two respondents responded that they would increase their tenants' rental or a levy to recover the additional costs paid of carbon tax paid;
- Two respondents responded that this is a difficult situation, as the current economic conditions and financial difficulties have an effect on the ability of tenants to pay increased rent or levies;
- Five respondents once again indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio, they cannot comment as it is being reviewed by their operational finance department or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.35: Responses received for Question 10

	Responses received	Number of responses
Response 1	That is a theoretical option, tenants will not pay more in the current economic climate	1
Response 2	Any additional cost from an operational or development point of view, whether it is tax or interventions to reduce tax is likely to eventually result in an increase in rental	1
Response 3	We are currently not in a position to make any formal comment on this, as it is being reveiwed by our operational finance department	1
Response 4	If it has additional costs then this will be passed on to the tenants	1
Response 5	There will definitely be an attempt at least to do this, because a lot our costs are recovered. Tenants in the retail sector however are also under financial pressure at the moment so as landlords we can't always squeeze them too hard because it could result in vacancies. Most of our tenants are National retailers with complicated and extensive specifications on their fit outs and operational approaches, so it will be difficult to make adjustments unless they are forced to. This will also take a lot of time and effort to get right.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that respondents are split whether they will increase their tenants' rental/ levies to recover their operational expenses or not increase their tenant's rental/ levies due to the current economic conditions and financial constraint. This can be seen as a no-win situation. It is also noted that some developers are hesitant towards answering the question, indicating that they are not yet sure how to handle the recovery of carbon tax.

Question 11: What changes will you bring to your new buildings to make your carbon tax amount payable as low as possible?

Of the 17 respondents:

- Three respondents responded that they would make the most cost-effective changes first, continue with the ESG strategy to transition their new buildings and investigate the big energy consumers (i.e., mechanical systems and kitchen appliances);
- Two respondents responded that further investigation is needed on the details of carbon tax;
- Four respondents once again indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and

- Six developers opted not to participate.

Table 4.36: Responses received for Question 11

	Responses received	Number of responses
Response 1	The most cost effective changes first	1
Response 2	At this point, we have not analyzed any of the details regarding carbon tax and have not implemented any interventions.	1
Response 3	We will continue to stick to our ESG strategy to transition the buildings - details of such strategy can be found in our ESG report. Unfortuntaltey we are unable to comment further than this	1
Response 4	This will need more investigation	1
Response 5	We will be forced to look at our big consumers (HVAC systems and kitchen appliances) and apply pressure to get the consumption down. From a landlord point of view we can only really control certain portions of a building like insulation, orientation, etc to try and limit the need for some of the big consumers like HVAC, but ultimately our hands are tied to an extent with what tenants decide to install in their premises. The leases signed on new developments will therefor have to address the issue, and could result in tenants not wanting to or be able to sign new leases so it is a complicated approach. Accurate data and implications will be needed before even considering applying it to leases.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that respondents that are large sized developers have ESG systems in place for the carbon efficiency transformation on their buildings and make cost-effective changes by reducing inadequate energy systems. Some small and medium sized developers still need to do further investigation and it noted that some developers are hesitant towards answering the question, indicating that they are not yet sure what changes to implement.

Question 12: What changes will you bring to your existing buildings to make your carbon tax amount payable as low as possible?

Of the 17 respondents:

- Two respondents responded that they would make the most cost-effective changes first, investigate the big energy consumers (i.e. mechanical systems and kitchen appliances), usage efficient utility meters, and utility monitoring and billing;
- Two respondents responded that further investigation is needed on the details of carbon tax;

- Four respondents once again indicated that they cannot answer as they do not know much what the carbon tax will entail for them and their property portfolio or they lack clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- Two respondents chose not to answer the question; and
- Six developers opted not to participate.

Table 4.37: Responses received for Question 12

	Responses received	Number of responses
Response 1	The most cost effective changes first	1
Response 2	At this point, we have not analyzed any of the detail regarding carbon tax and have not implemented any interventions	1
Response 3	No answer	1
Response 4	This will need more investigation	1
Response 5	Same as above, but even more difficult. You will have to wait for lease renewals or new tenants to come into buildings for these changes to tenant operations to be implemented. We have started changing all our water and electrical meters in our portfolio and have established a utilities department that is responsible for monitoring and billing the consumption of tenants. We realized that we have very limited knowledge on actual consumption and therefor could not really identify problem areas. Our utility monitoring and billing used to be outsourced which further contributes to a lack of accurate information. With our whole portfolio managed in-house we will be able to identify opportunities better and try and implement changes, but as mentioned this is difficult without knowing where the main problems are.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it can be concluded that respondents that are large sized developers make cost-effective changes by reducing inadequate energy systems. Some small- and medium-sized developers still need to do further investigation and it noted that some developers are hesitant towards answering the question, indicating that they are not yet sure what changes to implement.

Question 13: Do you anticipate started upgrading your buildings soon to be in line with the SA's 2030 and 2050 goals to be net zero-carbon? Please explain when, how and why.

Of the 17 respondents:

1. Two respondents answered that they would start upgrading their buildings or were already in the process of transitioning their buildings in line with the 2050 net zero goals;
2. One respondent answered that they did not plan to start upgrading their buildings as the criteria must first be broadcasted for the baseline per building to be assessed;
3. One respondent answered that they currently implement saving measures to comply with current regulations and where it had a financial benefit but did not consider upgrades purely based on carbon tax;
4. One respondent answered that they would start considering upgrades when carbon tax became applicable but did not know enough to further answer the question;
5. Four respondents indicated that they could not answer as they did not know what the carbon tax would entail for them and their property portfolio or they lacked clearance from their HR department to answer the question;
6. One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
7. One respondent chose not to answer the question; and
8. Six developers opted not to participate.

Table 4.38: Responses received for Question 13

	Responses received	Number of responses
Response 1	Should the implementation of the tax is as per these dates then yes - however there is a wave of resistance from major property owners/organizations to postpone the implementation	1
Response 2	At this point we implement energy saving measure to comply with current building regulations in new developments and where it has a financial benefit in terms of energy consumption. We are not considering upgrades to the building based purely on the possible carbon tax. Decisions on upgrades to building is determined by "normal" operational / maintenance requirements or the pursuit feasible developments	1
Response 3	We have already started to ensure our buildings will be able to transistion to the 2050 net zero goals - please refer to our ESG report for full information of the initiatives we have undertaken and what we have in the pipeline	1
Response 4	No, the criteria must first be promulgated so that the baseline per building can be assessed	1
Response 5	Well as soon as the forced tax and other changes in building regulations are applicable. We have never had any pressure on any of our developments from authorities when getting building plans or occupancy certificates approved. I honestly don't know enough to explain how yet...	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it was concluded that respondents from large-sized developers were already in the process of upgrading their buildings or would start to upgrade when carbon tax was implemented. Some small- to medium-sized developers would not upgrade their buildings solely based on the implementation of carbon tax, the standards must first be announced for them to access the baseline per building or when the carbon tax becomes applicable, but they indicated that they did not know much to answer the question in more detail.

Question 14: How do you think will the economy react to in implementation of carbon tax on residential, commercial and industrial properties?

Of the 17 respondents:

- Four respondents responded that the economy would react negatively towards the implementation of a carbon tax due to financial pressures, decreased profits, the current economic state and tenants having high expenses. Therefore, there would be pushback towards implementing a carbon tax;
- One respondent noted that it depended on what the thresholds were and how it was administered, but it remained unclear what the implementation of carbon tax would entail;

- Four respondents indicated that they could not answer as they did not know much the carbon tax would entail to them and their property portfolio or they lacked clearance from their HR department to answer the question;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.39: Responses received for Question 14

	Responses received	Number of responses
Response 1	Extremely negative - there is no incentives other than the avoidance of tax. The property sector can hardly afford further cost increases and thus investment in property will see a further decrease with all the socio economic hardship associated with same	1
Response 2	I think the industry will comply with legislation and implement sensible energy saving measures as much as possible, but if the cost of carbon tax or measures to reduce carbon tax become to high, affecting affordability and profits there will be pushback from the industry	1
Response 3	This is very speculative and full of assumption and conjecture. I don't think people realise that they already pay a form of carbon tax in a number of items that they already purchase and consume, and it will also depend on how it is administered and what the thresholds are	1
Response 4	It is going to negatively affect the property industry	1
Response 5	Extremely negative reactions can be expected in my opinion. Most developers and tenants are under enormous pressure already. We pay higher than acceptable rates for utilities, and we pay ridiculous rates and taxes while still being forced to spend large amounts of money on additional systems and operational requirements to ensure that the buildings operate sufficiently due to a lack of support or service delivery from Municipalities. To add another expense to the list might actually break some tenants and make it impossible for them to continue with their normal operations, especially smaller local tenants with low profit margins already. It will surely have the same affect as inflation with the cost of living going up because property owners and occupants will not have a choice but to increase their prices.	1
Response 6	Currently not in a position to make any formal comment on this	1
Response 7	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 8	We cannot answer as we know little about what carbon tax entails on our portfolio	1
Response 9	We cannot answer as we only starting to investigate carbon neutral buildings now	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it was concluded that the majority of the respondents believed that implementing a carbon tax on the property industry would be negative and there would be pushback from tenants and/or the public. In addition, it was noted that some developers were hesitant towards answering the question as they were unsure how the economy would react to implementing a carbon tax or how the implementation of the carbon tax would affect the industry.

Question 15: Would you like to add anything else?

Of the 17 respondents:

- Seven respondents answered that they would not like to add anything else to the questionnaire or interview;
- One respondent answered that it is not good timing for carbon tax without positive incentives for property developers and how the tax would be managed, creating a burden on developers and their tenants;
- One respondent indicated that they did not focus on carbon tax currently as the current economic conditions created highly competitive margins and not understanding the proper extent of carbon tax it was difficult to know what financial benefits there might be;
- One respondent expressed a desire to participate electronically but did not respond to any further communication, suggesting withdrawal from the research;
- One respondent chose not to answer the question; and
- Six developers opted not to participate.

Table 4.40: Responses received for Question 15

	Responses received	**Number of responses**
Response 1	It is unfortunate timing of the implementation and the lack of positive incentives for property developers, view this as just another burden. The management of the taxes generated is also questioned	1
Response 2	No	1
Response 3	No	1
Response 4	No	1
Response 5	It is not because we don't realized the long term consequences of not being sustainable that we don't put a lot of effort into it now, but the economic climate forces extremely competitive margins on developers and therefore change without understanding the financial benefit is difficult to currently justify.	1
Response 6	No	1
Response 7	No	1
Response 8	No	1
Response 9	No	1
Response 10	Agreed to participate, but did not respond further, therefore chose to not participate	1
Response 11	No answer	1
No Response	Choose to not participate	6
Total Responses		**17**

Based on the responses gathered from respondents, it was concluded that some respondents believed that implementing a carbon tax on the current economic conditions would not be good, as it would put a strain developers and tenants due to the uncertainty of positive incentives, how the tax would be managed, uncertainty of financial benefits or what the affect would be on the competitive margins.

4.4 Summary

Data from 50 EDGE-certified office projects was examined and extracted, by focusing on the prevalent factors that provided energy, water and building material savings. The extracted data was used to create a carbon efficient office building model that promoted reductions in carbon emissions and savings (Table 4.41).

Table 4.41: Proposed SA carbon efficient office building model promoting carbon emission savings

Office building elements		Category
Window to wall ratio		Energy
1	Window to wall ratio is reduced: Ideally 30%	
Shading elements		
2	External shading elements: Having an average shading factor of 0.48	
Reflective coatings		
3	External roof with reflective coatings: White coloured coating with SRI of 100	
4	External walls with reflective coatings: White or stone coloured coating with SRI ideally higher than 50	
Insulation		
5	Insulation to the roof: 95 mm thick fibre and wool insulation	
6	Insulation to the external walls: 1. 95 mm thick fibre and wool insulation, or 2. 78 mm thick EPS, or 3. 65 mm thick XPS insulation depending on specialist design	
Glazing		
7	High thermal performance glazing: 8 mm thick grey glazing	
Cooling systems		
8	VRF cooling system: Groundwater source < 40 kW	
Energy-saving lighting		
9	External and internal areas consisting of energy-saving lighting with LED lamp types	
10	Staircases and passages have lighting controls with LED lamp types	
11	Open plan offices, bathrooms and conference rooms have occupancy sensors with LED lamp types	
Electricity meters		
12	Smart electricity meters	
Solar PVs		
13	Solar PVs: Replacing 25% or more of the annual energy consumption	

Heated water generation (Optional)		
14	Spacing has a high efficiency condensing boiler: Delivering 98% energy efficiency	
15	Heat pump water generation system: Delivering 100% energy efficiency	
Offsite renewable energy procurement (Optional)		
16	Offsite renewable energy procurement	
Effective water flush systems		Water
17	Urinals and faucets have effective water flush systems: Flush rate of 4 L/flush or lower	
18	Water closets have effective water flush systems: Flush rate of 6 L/flush or lower	
Faucets and aerators		
19	Bathrooms and kitchen sinks have low-flow faucets: 4. Kitchen sinks to have a flow rate of 6 L/minute or less 5. Wash basin taps to have a flow rate of 2 L/minute or less	
Water recovery systems		
20	Rainwater harvesting system: Collecting and recycling rainwater	
21	A recycling and black water treatment system: Treating wastewater and recycling through treatment to repurpose on site	
Sundry water saving elements		
22	Smart water meters: To monitor water consumption	
Floor structure		Materia ls
23	*In situ* reinforced concrete with more than 30% PFA	
Roof structure and covering		
24	*In situ* reinforced concrete with more than 30% PFA	
Internal and external walls		
	Internal walls	
25	Internal walls: Partitioning (Plasterboards on metal studs)	
	External walls (Optional)	
26	External walls: Certain walls consisting of aluminium profile cladding	
	Internal and external walls	
27	Internal and external walls: Autoclaved aerated concrete blocks	

Insulation in walls and roof		
28	Insulation in walls: Glass or mineral wool	
29	Insulation in roof: Glass or mineral wool	
Floor covering		
30	Finished concrete floor	
31	Ceramic tiles	
Windows		
32	Aluminium window frames	
Existing building elements kept: Re-using existing elements eliminates the embodied energy of new materials, as the embodied energy will be nought and is the most desirable option		
33	Keeping majority existing internal and external walls during renovations	
34	Keeping existing floor and roof construction during renovations	
35	Keeping majority existing floor coverings during renovations	
36	Keeping existing windows during renovations	

Abbreviations: expanded polystyrene (EPS), extruded polystyrene (XPS), photovoltaics (PV), pulverised fuel ash (PFA), solar reflectance index (SRI), variable refrigerant flow (VRF)

The proposed model was tested in a scenario where a commercial building of 2 728 m^2 was designed by standard office construction methods (Scenario A) and then the same commercial building was designed with the proposed carbon efficient office building model (Scenario B). By comparing the two scenarios, the carbon efficient office building model provided more favourable results. Table 4.41 shows that Scenario B offers more energy and water savings, as well as more operational carbon emission savings. Scenario A had a final energy use of 24,633.19 kWh per month, and Scenario B had 11,646.72 kWh per month, saving 12,986.47 kWh per month. Scenario A had a final water use of 390.79 m^3 per month, and Scenario B had 70.59 m^3 per month, saving 320.20 m^3 per month. Scenario A had operational carbon emissions savings of 138.40 tCO2 per year, and Scenario B had operational carbon emissions savings of 271.45 tCO2 per year, giving additional savings of 133.05 tCO2 per year.

Table 4.42: Findings from Scenarios A and B

	Scenario A	Scenario B	
Final energy use	24,633.19	11,646.72	kWh per month
Final water use	390.79	70.59	m^3 per month
Carbon emissions	252.40	119.40	tCO2 per year
Operational carbon emission savings	138.40	271.45	tCO2 per year
Annual carbon tax	ZAR 47,956.00	ZAR 22,686.00	per year

Scenario A's office building emitted 252.40 tCO2 per year which meant that the developer/property owner would need to pay ZAR 47,956.00 carbon tax per year for one building. Scenario B's office building emitted 119.40 tCO2 per year which meant that the developer/property owner would need to pay ZAR 22,686.00 carbon tax per year for one building. This was a saving of ZAR 25,270.00 (more than a 50% cost saving) that did not need to be paid to SARS should the developer/property owner decide to develop the building based on Scenario B. Therefore, the proposed SA carbon efficient office building model would reduce the influence of carbon tax on the developer/property owner.

When the cumulative savings across multiple buildings were considered, small individual savings added up for developers with an extensive commercial building portfolio. A typical saving of ZAR 25,270.00 per building results in a total saving of ZAR 126,350.00 for five buildings of the same type and size. This revealed how the benefits of adopting the carbon efficient office building model became evident as the scale of the commercial building portfolio increased.

Sufficient data was obtained from the literature review to design an office building model that could be used as a guideline for developers to ensure that their buildings would be carbon efficient and/or zero-carbon buildings that would reduce the influence of carbon tax on commercial buildings. This office building model was tested and compared with traditional office building construction, and it was concluded that the office building model provided carbon tax savings.

Feedback from developers verified that implementing carbon tax was the current problem, although the policy was designed effectively, the country was delaying its efforts to decarbonise as there remained a dependence on coal and lack of awareness among developers. Responses also indicated that by implementing a carbon tax in the current economic conditions would not be good, as it would put a strain on developers and tenants due to the uncertainty of positive incentives, how the tax would be managed, uncertainty of financial benefits or what the affect would be on the competitive margins.

Responses from the questionnaires and interviews indicated that larger-sized developers were up to date with the current affairs of carbon tax and the implications thereof on their property portfolio. Larger-sized developers were already incorporating transitions into their buildings and releasing ESG reports to the public to show their commitment to the goals on net zero-carbon emissions in 2050. Small- to medium-sized developers were less updated on the topic of carbon tax and how it would affect their property portfolio, or they only became aware of it recently, indicating a lack of knowledge or awareness. This was substantiated by what the larger-sized developers answered that there was a lack of awareness from government to ensure that all relevant parties were informed about the implementation of carbon tax and the details thereof.

Some of these developers were hesitant to answer as they knew little about carbon tax and what it entailed, how they would implement changes in their buildings or whether they would declare and pay carbon tax due to not knowing how the relevant authorities would administer the carbon tax. NSF Consulting (2024) stated that some respondents might be reticent to disclose information or felt unwilling to disclose sensitive information as it might cause embarrassment or threaten their company's image. Some developers disclosed that carbon tax classified as a sensitive topic. Additional reasons why some developers chose to not participate or respond were that they might be ignorant about the topic, they were uninterested, they were too busy or ignored correspondence.

From this data, the office building model and responses received in Chapter 4, research could now be concluded in Chapter 5.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter focuses on the conclusions based on the study's findings identified in Chapter 4. Research results based on the data gathered and analysed, resistance towards a Net Zero community, contributions needed for the practice and recommendations are discussed in this Chapter.

5.2 Research Results

5.2.1 Summary: Data Gathered and Analysed

Responses from the questionnaires and interviews indicated that larger-sized developers were up to date with the current affairs of carbon tax and the implications thereof on their property portfolio. Larger-sized developers were already incorporating transitions into their buildings and releasing ESG reports to the public to show their commitment to the goals on net zero-carbon emissions in 2050. These commitments stemmed from their international relationships. However, these respondents noted that tax advisors or auditors made them aware of this implementation, indicating that there was a lack of awareness from government to ensure that all relevant parties were well informed about the implementation of carbon tax and the details thereof.

One larger-sized developer aiming to be carbon neutral was Growthpoint. De Klerk (2023) noted that green electricity and developments are the solution to minimise the human development impact, not only in SA, but the world. Water shortages and electricity deficiency are the main problems that SA currently face, meaning that green buildings and electricity are not a priority for the country. Growthpoint's aim is to contribute to this by minimising their carbon footprint by using the ESG performance (de Klerk, 2023). De Klerk (2023) stated that their aim is to have all their buildings in their portfolio carbon neutral by 2050, the goal is to raise renewable energy use in 2026 by five times and ensure to reduce their GHG emissions with 25%.

Hence, it was observed that the first sub-problem hypothesis that stated that net zero-carbon buildings were a reality for SA was accurate. However, note that small- to medium-sized developers were less updated on the topic of carbon tax and how it would affect their property portfolio, or they only became aware of it recently, indicating a lack of knowledge or awareness.

This was substantiated by what the larger-sized developers answered that there was a lack of awareness from government to ensure that all relevant parties were informed about the implementation of carbon tax and the details thereof.

These findings support that SA has still a long way to go in comparison to other countries with regards to their commitment to a zero-carbon community, but the designed office building model can be used internationally as a guideline in countries with similar climate conditions which is supported through similar international studies.

Some of these developers were hesitant to answer as they knew little about carbon tax and what it entailed, how they would implement changes in their buildings or whether they would declare and pay carbon tax due to not knowing how the relevant authorities would administer the carbon tax.

Small-, medium- and larger-sized developers were all in agreement that the impact of the implications of carbon tax would be negative which could result in more economical constraints on the country and financial pressures on both tenants and developers. These developers noted that it is not as easy as increasing rent or levies to recover these expenses because the current financial difficulties make it hard to implement these increased rates. Leaving the developers with the following questions:

- "Would we need to absorb these expenses to keep our current tenants?"
- "Do we increase the rentals or levies and possibly loose tenants and rental?"

NSF Consulting (2024) stated that some respondents might be reticent to disclose information or felt unwilling to disclose sensitive information as it might cause embarrassment or threaten their company's image. Some developers disclosed that carbon tax classified as a sensitive topic. Additional reasons why some developers chose to not participate or respond were that they might be ignorant about the topic, they were uninterested, they were too busy or ignored correspondence. Hence, it was observed that the second sub-problem hypothesis that stated that there would be resistance to convert their buildings or pay carbon tax can be accepted.

Mandy (2023) stated that the first phase of the carbon tax has been prolonged for three years, spanning from January 2023 to 31 December 2025. This suggests a potential delay in the transformation of current commercial structures and the construction of new ones into net-zero carbon emitting buildings. However, it also offers developers an opportunity to ready themselves for this shift toward a net-zero carbon emitting community. During this timeframe, companies impacted by the initial carbon tax phase have access to transitional support measures, such as revenue-recycling initiatives and tax-free allowances.

Carbon credit was introduced to limit the amount of GHG emissions being produced (Gootkin, 2023). Therefore, developers incorporated ESG reporting to reduce the impact of their operations on the environment by buying carbon credits from projects that had reduced GHG emissions or investing in their own projects. However, it is not a voluntary market as only most large developing companies (with international ties) are committed to reducing their GHG emissions.

Tsatsi (2023) stated that the increased demand of ESG-aligned products and practices from companies are needed to minimise the global threat of climate change, unethical practices, resource depletion and rising pollution. Developing companies incorporated ESG into their operations, services and products, as well as aligned their values with their investment choices and strategies. With ESG integration, all the opportunities and risks were incorporated into their investment decision-making procedures. Investors' portfolios would benefit from integrating ESG, as it was about thinking how companies could save the planet, live responsibly while preserving the environment and securing a future financially.

Unfortunately, there is a demand for resource efficiency because of the crisis SA has with water and electricity. The IFC (2022) stated that ZAR 300 million was provided by Business Partners Limited for a green fund. SA's state-owned Industrial Development Corporation planned to invest USD 1.2 billion over the next five years (from 2023 to 2027) into green developments, USD 10 million was invested by the EPPF and USD 30 million by the SA NHFC to incentivise green developments. The SA government showed their support by announcing to launch a building energy efficiency programme which was led by the DPWI and when developers or homeowners plan modifications to their buildings or create new developments, they needed to meet the energy efficiency standards. Therefore, international support is needed to support these actions as the community has a limited capacity and there are socio-economic risks involved. These risks include persons not being able to afford greener technologies due to high prices and low income in the coal community due to lower coal use. SA needs financial, technology and trade support, as well as capacity and skill development. Note that more than job creation is required to guarantee the fairness of this transition.

Sharpe (2023) is of the opinion that SA requires ZAR 250 billion to invest in infrastructure for this transition, but the question is whether investors are comfortable to invest in projects in this country. Political differences caused delays in the decarbonation progress which might make investors hesitant to invest. Sharpe (2023) notes:

> if you look at the politics around environmentalism, you have people saying climate change was largely caused by developed nations polluting, so why should we now pay the price by not using the resources that we have in abundance? It only takes a change in the ANC leadership for shale gas reserves to be exploited, for example. The unpredictability within the ANC presents a risk for investors.

An economy that remains carbon intensive is destined to become less competitive, SA would be less competitive internationally if it still relied on fossil fuels to produce electricity. There would be a great shift for this country when capital could be invested into renewable off-grid energy.

Currently, it is not mandatory that the private sector must transition to zero-carbon, including the need to transfer skills to marginalised communities relying on the coal value chain. Mpumalanga is the province with the highest risk of this. One person working in the coal industry supports 10 people (Sharpe, 2023). The private sector needs to be more proactive in their transition which would in turn would increase the opportunities for investment. However, a few challenges need to be overcome (e.g. political instability, the debt-to-GDP ratio, being grey listed and the downgrading of the credit rating). Therefore, transparency, governance frameworks and a creditable plan is required so that investors know what would happen with their money. However, it is important that the government creates awareness throughout the property industry so that developers and owners could prepare themselves for this commitment to upgrade their buildings and the possible expenses involved should they not wish to proceed with the upgrades.

The NBI (2022) noted that this transition might preserve the economy, create new green sectors and secure long-term competitiveness. However, it needed to be combined with intended efforts where the whole SA community is included, and the developmental needs are met. Actions by individuals alone would not be adequate to meet this challenge, an organized and collaborated approach are required to decarbonise successfully. However, it would be met with resistance from the industry and the public where increased expenses are involved and possible job losses in the coal sector.

5.3 Resistance Toward Net Zero

Mishra and Isazada (2021) state that change cannot be avoided in today's world of uncertainty, complexity, ambiguity and instability. The problem is when change initiatives are met with resistance by companies. When companies are content in their current state of operation, the probability for resistance will be higher. Change involves many unknowns and causes anxiety, fear, ignorance and bias leading to resistance. Familiarity is a comfort zone where some companies prefer to stay as they fear the unknown, increasing the likelihood of reasons to change will be sabotaged or ignored. One example of resistance that was in SA was a billboard located near Doringkloof by a group called, Friends of Science (2022). On the R21 near Doringkloof, Centurion, Gauteng (Figure 6.1[a]) a billboard was erected by the Friends of Science Society stating that "Net zero is a hoax to enslave you". The Scholarly Community Encyclopedia (2023) states that the Friends of Science is a non-profit advocacy primarily based in Canada that rejects the idea that it is scientifically concluded that humans are the main reason for climate change.

(a) (b)

Figure 5.1: (a) "Net zero is a hoax" sign (Friends of Science, 2022)
(b) Photograph taken on the R21 (Google Maps)

5.4 Contributions to Practice

This research will be valuable to all stakeholders in the SA construction industry. This includes the public sector; clients; investors; quantity surveyors (QSs); students; developers; property owners and managers; and all professionals (e.g. architects, the engineering profession, and other building consultants). This will give them a better understanding of what net zero-carbon buildings and the carbon tax on their buildings will entail. This might encourage them to start changing to a low-carbon construction industry. It will provide a basis for the current progress in SA regarding net zero-carbon buildings and the implementation of a carbon tax.

In addition, a comparison will be made to other countries and their commitments and progress to becoming low-carbon economies. Stakeholders (the public sector, clients in the building industry, developers, property owners and managers, students, and all other professions in SA) will benefit from this research, as it will improve the progress in fighting climate change and contribute to the success of achieving WorldGBC goals.

Currently, there were some guidelines that could be followed by developers to develop or refurbish commercial buildings to be carbon neutral or net zero. However, there was not a proper model specific to SA's climate conditions that could be used by developers to assist them in developing more sustainable buildings. For developers with a substantial number of commercial buildings in their portfolio, the potential savings could be significant. The proposed SA carbon efficient office building model optimizes energy efficiency and operational costs. Furthermore, it could contribute to long-term cost savings for developers by lowering operational expenses, maintenance costs and other utility expenditures. Apart from the direct financial savings, adopting sustainable practices and an energy-efficient building model could improve the buildings' overall market value and draw environmentally conscious tenants. Which would lead to higher occupancy rates, improved tenant satisfaction and higher rental income that would convince developers of the idea of transitioning to carbon neutral and net zero-carbon buildings.

A net zero-carbon building could be certified, when the onsite energy savings were more than 40% compared to the base case building and where the operational emissions offset was 100% (EDGE, 2023a). This carbon efficient office building model is an ideal net zero-carbon model, when solar PVs are used to generate 100% electricity (and excess electricity is fed back into the grid), and efficient water use for savings in water consumption.

As identified, the Vodafone SSIC is a perfect example in SA to follow that supports the proposed SA carbon efficient office building model:

- Enough energy was generated for building operations that could feed the remaining energy into the grid;
- Grey water was reused for irrigation and toilet flushing;
- Energy-efficient lighting was used;
- Concrete comprised 60% cement alternatives;
- Sixty per cent of the steel was reused; and
- A waste management and recycling system was in place.

Therefore, the proposed SA carbon efficient office building model would be an ideal guideline when designing a new commercial building project or refurbishing an existing commercial building. Hence, it was observed that the third sub-problem hypothesis was substantiated which stated that measures taken to obtain net zero-carbon buildings with actions implemented by the larger sized developers with their ESG reports and the Vodafone SSIC.

In conclusion, the hypothesis of the main problem which stated that there was insufficient exposure in SA of zero-carbon buildings and the influence of carbon tax being implemented would motivate the conversion to net zero-carbon buildings was verified. Currently, there is a substantial lack of exposure to implementing carbon tax as most small- to medium-sized developers lacked knowledge of carbon tax and what it entails. While carbon tax is known to larger developers, they are motivated to convert their buildings in line with the 2050 net zero goals. When certainty and awareness are given to small- to medium-sized developers, they would be motivated to convert their buildings to zero-carbon buildings.

5.5 Recommendations

The GBCSA (2019) states that “climate change poses the greatest threat facing humankind” and SA has a responsibility to play its role in the global effort. Habitual behaviour can no longer be clung to, SA must assess how it can adapt to ensure resilience in a low-carbon economy. Oxford (2019) supports this by stating: “If we don’t advance with intent to reduce our emissions and adhere to the global conversation, then we run the risk of being an even bigger pariah on the global stage”. Furthermore, SA should consider this as a critical benefit to use as a weapon when trading in the global arena. However, improvements need to be made where sectors need to become compliant (e.g., the construction industry and Eskom), to imitate best practises which are aligned with the rest of the world.

Legg (2019) states that companies that use this window to evaluate the carbon emission risk exposures and start the much-needed process to transition into low carbon business practices would be better equipped for a carbon tax.

5.6 Summary

Sufficient data was obtained from the literature review to design an office building model that could be used as a guideline for developers to ensure that their buildings would be carbon efficient and/or zero-carbon buildings that would reduce the influence of carbon tax on commercial buildings.

This office building model was tested and compared with traditional office building construction, and it was concluded that the office building model provided carbon tax savings.

Feedback from developers verified that implementing carbon tax was the current problem, although the policy was designed effectively, the country was delaying its efforts to decarbonise as there remained a dependence on coal and lack of awareness among developers. Responses also indicated that by implementing a carbon tax in the current economic conditions would not be good, as it would put a strain on developers and tenants due to the uncertainty of positive incentives, how the tax would be managed, uncertainty of financial benefits or what the affect would be on the competitive margins.

However, the problem is when change initiatives are met with resistance by companies. When companies are content in their current state of operation, the probability for resistance will be higher. Change involves many unknowns and causes anxiety, fear, ignorance and bias leading to resistance to move toward a net zero community.

The proposed SA carbon efficient office building model optimizes energy efficiency and operational costs. Furthermore, it could contribute to long-term cost savings for developers by lowering operational expenses, maintenance costs and other utility expenditures. Apart from the direct financial savings, adopting sustainable practices and an energy-efficient building model could improve the buildings' overall market value and draw environmentally conscious tenants. Which would lead to higher occupancy rates, improved tenant satisfaction and higher rental income that would convince developers of the idea of transitioning to carbon neutral and net zero-carbon buildings.

Further research can be explored includes the implications of applying carbon tax to the property sector, assessing SA's ability to meet the 2030 and 2050 net zero targets, the cost to become net-zero compliant and identifying potential gaps in administering carbon tax and carbon credits.

Carbon tax and implementing constructing net zero buildings might be a lengthy and difficult process to manage, but it might set SA on a far greater economically powerful path. It is important for developers to consider the long-term financial benefits and environmental impact. By taking a holistic approach and considering the cumulative savings across their portfolio, developers can make informed decisions that align with their financial and sustainability goals.

There is a pressing need for the government to initiate a substantial campaign aimed to increase public awareness regarding carbon tax, its implementation, the benefits of converting buildings to net zero-carbon and the commitments made by SA to achieve the 2030 and 2050 targets. Interacting boards or meetings with the government and GBCSA are recommended so that all developers (small, medium and large companies) could raise their concerns concerning:

- Increased expenses, drawbacks and resistance they might face;
- How expenses could be recovered without putting pressure on tenants; and
- How carbon tax will be evaluated and administered, to contribute to the growth of the economy.

Clear guidelines should be distributed to assist developers in designing, constructing or renovating buildings with greater carbon efficiency. In addition, support from specialists in carbon-efficient building practices should be made accessible. Universities could integrate the idea of applying carbon tax to properties into their curriculum, enhancing students' education in the construction industry programmes. This approach aimed to reinforce their awareness, guide and inspire students to develop sustainable solutions that might reduce the impact of carbon emissions and taxes on developments for their future clients.

Despite research completed on carbon tax and its application in various countries, SA lacks research on implementing carbon tax in the property sector. It is recommended to conduct future investigations into the potential consequences of carbon tax on the property sector, particularly in the residential and industrial industries. This research should explore:

- The implications of applying carbon tax to the property sector;
- How other building services can contribute to a net-zero commercial building, such as Variable Voltage Variable Frequency (VVVF) Lifts, etc.;
- Assess SA's ability to meet the 2030 and 2050 net zero targets;
- The construction cost to develop a net-zero commercial building versus the carbon tax payable on the building;
- The cost to become net-zero compliant; and
- Identify potential gaps in administering carbon tax and carbon credits.

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ANNEXURE A

ETHICS APPROVAL LETTER

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

28 May 2023

Reference number: EBIT/33/2022

Mrs P Rogers
Department: Construction Economics
University of Pretoria
Pretoria
0083

Dear Mrs P Rogers,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Approval is granted for the application with reference number that appears above.

1. This means that the research project entitled "Influence of carbon tax on office buildings in South Africa" has been approved as submitted. It is important to note what approval implies. This is expanded on in the points that follow.

2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Research Ethics Committee.

3. If action is taken beyond the approved application, approval is withdrawn automatically.

4. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.

5. The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof K.-Y. Chan
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

ANNEXURE B

COPY OF QUESTIONNAIRE

Influence of carbon tax on office buildings in South Africa

Dear Sir/Madam,

I am a PhD student in the Department of Construction Economics, University of Pretoria.

My research titled “Influence of carbon tax on office buildings in South Africa” is about identifying what the influence of carbon tax will be on new and existing office buildings in South Africa, especially the influence of this tax on developers and property owners with a big property portfolio.

My study aims to identify the influence of carbon tax on office buildings, it will contribute to examine the current state and situation of carbon tax in this country, as well as assist developers, property owners, property managers and other stakeholders with strategies on how to reduce the impact of carbon tax on their buildings, for example strategies like converting existing buildings into zero carbon buildings.

The purpose of this questionnaire is to identify the influence of carbon tax on office buildings and to synthesize strategies on how to reduce the impact of carbon tax on office buildings that would be suitable in a South African context.

You were chosen as a respondent because you are a property owner and/ or property developer that has a wide range of commercial assets in your portfolio.

Your participation is voluntary and you can withdraw at any time without penalty. Throughout the survey your privacy will be protected and your participation will remain confidential. I do not wish to analyze data individually and all the data will be transferred to a computer programme to analyze the entire group. This means that you are assured of anonymity.

If you agree to participate, please complete the survey that follows this covering letter. It should take about 30 minutes of your time at the most. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact me with the detail provided below.

Researcher's name: Paparouzkja Rogers
Email address: rogers.rouzkja@up.ac.za
Phone: 072 587 5822

University of Pretoria - Ethical Approval Letter

Approval from the Faculty Committee for Research Ethics and Integrity of the University of Pretoria has been granted.

1. 1. Do you have any buildings that are green star rated or constructed from sustainable materials? If yes, please specify what actions you have taken. If no, please specify why.

2. 2. Laski and Burrows (2017) define net zero carbon buildings as "highly energy-efficient buildings where all remaining operational energy use are from renewable energy, preferably being on-site but also off-site production in order to achieve net carbon emissions annually in operation".

   Zero carbon buildings are energy efficient, include green building materials and sustainability in order to reduce the greenhouse gas emissions that a building emits.

   Are you aware that South Africa has committed to have all existing buildings operate at Net Zero by 2050 and new buildings by 2030? If yes, please specify what actions you have started to take.

3. 3. Are you committed that your buildings have a minimal impact on the environment, to proactively reduce and control their carbon emission footprint from a truthful baseline, as well as to reduce the carbon footprint of your buildings? If yes, please explain why.

4. 4. Are you up to date with the current events taking place by the Green Building Council South Africa? Please explain how and why.

5. 5. Why do you believe to invest in green star-rated buildings?

6. 6. South African Revenue Services (SARS) (2020) describes carbon tax as new tax which is put into place in South Africa as a response to climate change, it is aimed to provide an affordable, cost effective and sustainable manner in which Green House Gas (GHG) emissions can be reduced. Carbon tax motivates consumers and companies to consider the negative adverse costs of climate change when they make decisions with regards to consumption, production, and investment decisions. SARS (2020) further explains that carbon tax also give effect to the “polluter-pays-principle”.

   Schedule 2 under the Carbon Tax Act 2019 sets out thresholds with regards to electricity use by building occupants, whether it being companies or tenants for commercial or residential electricity and heat use. The threshold for both residential and commercial operation activities are 10MW(th) installed input capacity for combustion activities resulting into emissions. The second phase will start in 2023 and property owners will be eligible to pay for carbon tax on their buildings of R 120 per ton.

   Are you aware that South Africa has enforced carbon tax which will be applicable to your property portfolio? If yes, who made you aware of this?

7. 7. With carbon tax coming into effect in 2023, does this worry you about having an additional tax to declare and pay? Please explain why.

8. 8. Will you declare your building electricity use to SARS to pay for the carbon tax? Please explain why/why not.

9. 9. How do you think carbon tax will affect your development and maintenance of buildings?

10. 10. Will you increase the rent of your tenants or add a levy to make up for the carbon tax? Please explain why.

11. 11. What changes will you bring to your new buildings to make your carbon tax amount payable as low as possible?

12. 12. What changes will you bring to your existing buildings to make your carbon tax amount payable as low as possible?

13. 13. Do you anticipate to start upgrading your buildings soon in order to be in line with the South Africa’s 2030 and 2050 goals to be net zero carbon? Please explain when, how and why.

14. 14. How do you think will the economy react to in implementation of carbon tax on residential, commercial and industrial properties?

15. 15. Would you like to add anything else?

16. 16. Would you like to receive a copy of the results? *Please fill in an email address (under the "other" option) where the results can be forwarded to.*

Mark only one oval.

- Yes
- No
- Other: ____________________

Thank you for your participation.

ANNEXURE C

TURNITIN SIMILARITY REPORT

PhD Quantity Surveying Thesis 2024 - P Rogers u14018642 (Amended TII - 06.07.2024).pdf

by P (Rouzkja) Rogers

Submission date: 07-Jul-2024 10:34AM (UTC+0200)

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ANNEXURE D

PROOF OF EDIT LETTER

Strikethrough
PROFESSIONAL ACADEMIC EDITING SERVICES

Louise Keuler
Academic Editor

M: 072 263 6805
E: louise.jean.greyling@gmail.com

Proof of Edit

UP|2024|02

To whom it may concern,

2024/03/15

Declaration

With this I certify that I, Louise Jean Keuler, was paid as freelance academic editor to format, edit and reference-check Paparouzkja Rogers' doctorate degree thesis ('Influence of carbon tax on office buildings in South Africa') for submission to the Department of Construction Economics, Faculty of Engineering, Built Environment and Information Technology, University of Pretoria (UP). It should be noted that as Ms Rogers' editor, I did not contribute to the content or research of the thesis. The work is entirely her own and my contribution to it was merely for the sake of clarity and readability.

Services rendered

Formatting	Editing	Reference-checking
• Applying all journal/style guide formatting for the general document. • Creating/correcting automatic table of contents, list of figures and tables. • This excludes applying journal/style guide formatting for in-text citations and references.	Correct, condense, organise and make any other modifications needed to produce a correct, consistent, accurate and complete work.	Checking in-text citations against reference lists, and applying all journal/style guide formatting for in-text citations and references.

Description	Fromatting, editing and reference-checking of doctorate degree thesis
Charged To	P Rogers
Received By	LJ Keuler

Sincerely,

LKeuler

Louise Keuler
Strikethrough | Owner

ANNEXURE E

EDGE CERTIFIED PROJECTS

						Technical solutions used			
Country	**Project Name**	**New or Retrofit**	**Description**	**Area**	**Certification Stage**	**Energy**	**Water**	**Materials**	**Total CO2 savings (annually)**
1. Mexico	Fibra MTY Offices	Retrofit	The Fibra MTY Offices, constructed in 1995, is an existing building which is refurbished. Technologies that are energy efficient and modern technology are used to elevate the building to a EDGE Advanced standard. Technical solutions and re-use of existing structural building elements created a building design which is sustainable with a lower carbon footprint, EDGE (2023).	898.00	Final EDGE Advanced Certification	This building consists of: • Low E coated glazing • A VRV (Variable Refrigerant Volume) cooling system • External and internal areas consisting of energy-saving lighting	This building consists of: • Water closets have effective water flush systems • Urinals and faucets have effective water flush systems • A recycling and black water treatment system.	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning used for internal walls • The existing flooring is kept, and nylon carpets used • Aluminium windows	26.92
Percentage savings in energy, water and embodied carbon						**40%**	**56%**	**73%**	
2. Philippines	Menarco Tower	New	The Menarco Tower is a newly constructed building with a population density of 8m² per occupant and features parking specifically allocated for green vehicles	25 876.75	Final EDGE Advanced Certification	This building consists of: • Window to wall ratio is reduced • External walls has reflective	This building consists of: • Auto shut-off faucets and/or aerators • Water	This building consists of: • In-situ reinforced concrete slabs • The roof having steel	879.88

			and bicycles. This building's goal is to be a green building without lowering the aesthetic value. Natural lighting is utilized, and curtain walls have an insulated glazing unit for spandrel and viewing panels which reduces the air-conditioning load while achieving optimum thermal comfort. This leads to lower electricity costs. Grey water is harvested from rainwater and air-conditioning condensate drains for landscape irrigation and maintenance,			paint • Insulation to the roof • Variable speed drives in AHU, • Refrigeration cases of higher-efficiency • External and common spaces, as well as passages have energy-saving lighting • Bathrooms have occupancy sensors • Skylights providing 50% daylight to the top floor area.	closets have effective water flush systems • Urinals and kitchen faucets have effective water systems	sheets and rafters • Internal and external walls of solid dense concrete blocks • Partitioning used for internal walls • Some external walls consisting of aluminium profile cladding	
Percentage savings in energy, water and embodied carbon						**41%**	**69%**	**35%**	
3. Ecuador	Produbanco Iñaquito	Retrofit	Produbanco Iñaquito is an existing office building that was refurbished in 2018 by incorporating existing structural elements. This building used energy-efficient solutions in	10 725.53	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External walls and roof have	This building consists of: • Water efficient plumbing features	This building consists of: • In-situ waffle concrete slabs	183.98

			order to minimize water and electricity use, as well as obtain a reduction in embodied energy by re-using existing building elements for a sustainable construction project with a lower carbon footprint.			reflective paint • Low-E coated glazing • Internal and external areas have energy-saving lighting • Staircases and passages have lighting controls • Open plan offices, bathrooms, closed cabins and conference rooms have occupancy sensors • Internal areas have daylight photoelectric sensors • Consumption based energy meters • Smart electricity meters		• Composite in-situ waffle concrete roof • External walls are kept as is • Partitioning used for internal walls • Ceramic tile and vinyl floors • Aluminium windows	

Percentage savings in energy, water and embodied carbon						43%	40%	47%	
4. Ecuador	Produbanco Ekopark	Retrofit	Produbanco Ekopark is an existing office development that uses energy-efficient solutions and existing building elements to obtain a 90% reduction of embodied energy for a reduced carbon footprint and a sustainable construction project.	11 660.16	Final EDGE Certification	This building consists of: • External shading elements• External roof has reflective paint • High thermal performance glazing • Internal and external areas have energy-saving lighting • Staircases and passages have lighting controls • Open plan offices, bathrooms, closed cabins and conference rooms have occupancy sensors • Internal areas have daylight	This building consists of: • Bathrooms and kitchen sinks have low-flow faucets • Water closets have effective water flush systems • Urinals faucets have effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning used for internal walls • The existing flooring is kept • The existing windows are kept	212.39

						photoelectric sensors • Consumption based energy meters • Smart electricity meters			
Percentage savings in energy, water and embodied carbon						**42%**	**37%**	**90%**	
5. Vietnam	Leadvisors Tower	New	Leadvisors Tower is a 25-story office building that incorporated energy and water-saving technologies their design.	24 539.00	Preliminary EDGE Certificate	This building consists of: • Low-E coated glazing • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting	This building consists of: • Bathrooms and kitchen sinks have low-flow faucets • Urinals faucets have effective water systems	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Internal and external walls of common brick with plaster and paintwork to external and internal walls • Medium weight hollow concrete blocks used for internal walls • Finished concrete floor • Aluminium windows	544.63

Percentage savings in energy, water and embodied carbon						**24%**	**42%**	**21%**	
6. Guatemala	MARN Despacho Superior	Retrofit	MARN Despacho Superior is an existing office building of 408m² that significantly reduced energy and water use, particularly energy embodied in materials.	408.33	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External walls have reflective paint • Air conditioning with air cooled screw chiller • Internal and external areas have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals have effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • The existing flooring of parquet/wood block finish is kept • The existing windows are kept	18.43
Percentage savings in energy, water and embodied carbon						**41%**	**43%**	**97%**	

7. Zambia	Standard Tower	New	Standard Tower is a new 6-storey office building where energy and water-saving technologies were incorporated into the design, construction, and internal operations of the building.	10 880.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Insulation to the roof • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting • Open plan offices, bathrooms and conference rooms have occupancy sensors • Solar photovoltaics providing 15.3% of electricity use	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals and kitchen faucets have effective water systems	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • In-situ reinforced concrete external walls • Medium weight hollow concrete blocks used for external and internal walls • Partitioning used for internal walls • Nylon carpets and ceramic tiles for floor finishes • Aluminium windows	85.13

Percentage savings in energy, water and embodied carbon						**50%**	**55%**	**34%**	
8. Indonesia	Gedung KLMS	New	Gedung KLMS is a one-story office building energy, and water-saving technologies were incorporated into the design, construction and internal operations of the building.	177.00	Final EDGE Advanced Certification	This building consists of: • Window to wall ratio is reduced • External walls and roof have reflective paint • Variable refrigerant volume (VRV) cooling system • Internal spaces have energy-saving lighting • Solar photovoltaics providing 22.5% of electricity use	This building consists of: • Water closets have effective water flush systems • Rainwater harvesting system	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Asphalt shingles on steel rafter roof construction • Autoclaved aerated concrete blocks used for external and internal walls • Ceramic tiles for floor finishes • Aluminium windows	24.97
Percentage savings in energy, water and embodied carbon						**59%**	**41%**	**68%**	

9. Kenya	Purple Tower	New	Purple Tower is a 62m-high, mixed-use development that includes 3 floors of retail space and 12 floors of office space. Energy and water-saving technologies were incorporated into the design, construction and internal operations of the building.	20 313.00	Preliminary EDGE Certificate	This building consists of: • High thermal performance glazing • External and internal spaces have energy-saving lighting • Open plan offices, bathrooms and conference rooms have occupancy sensors • Solar photovoltaics providing 20% of electricity use	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals and kitchen faucets have effective water systems	This building consists of: • Concrete filler slabs • Steel rafters with aluminium sheets for the roof • In-situ reinforced concrete external and internal walls • Ceramic tiles and finished concrete flooring for floor finishes • Aluminium windows	197.25
Percentage savings in energy, water and embodied carbon						**27%**	**41%**	**33%**	

10. Indonesia	MTH 27 Office Suites	New	MTH 27 Office Suites is an office building that consists of 13 floors of strata title offices and 4 basement parking floors.Green building design and green construction is used to achieve a sustainable office development	14 731.46	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • Roof has reflective paint • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal spaces have energy-saving lighting • Smart electricity meters	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Kitchen sinks have effective water systems • Rainwater harvesting system • A recycling and black water treatment system.	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Steel rafter roof construction with steel (zinc or galvanized iron) sheets • Aluminium clad sandwich panels used for external walls • Autoclaved aerated concrete blocks used for internal walls	856.47
Percentage savings in energy, water and embodied carbon						**42%**	**78%**	**24%**	
11. Indonesia	Sopo Del Office Tower – Sky Office	New	Sopo Del Office Tower is a mixed-use building consisting of 12 floors office space that utilizes resource-efficient design features and	12 000.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • High	This building consists of: • Bathrooms and	This building consists of: • In-situ reinforced concrete slabs	621.60

			technologies to minimize the impact on the environment and save on operational costs.			thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal spaces have energy-saving lighting • Smart electricity meters	showers have low-flow faucets • Water closets have effective water flush systems • Urinals and kitchen faucets have effective water systems • Rainwater harvesting system • A recycling and black water treatment system.	•In-situ reinforced concrete roof • Curtain walling used for external and internal walls • Cellular light weight concrete blocks used for internal walls • Ceramic tiles for floor finishes • Aluminium windows	
Percentage savings in energy, water and embodied carbon						**40%**	**82%**	**24%**	

12. Nigeria	MISA	New	MISA is a sustainable office building that aims to enhance the lifestyle of occupants by adding value through green building methods.	21 387.70	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • Insulation to the roof • Internal and external areas have energy-saving lighting • Bathrooms, closed cabins and conference rooms have occupancy sensors • Internal areas have daylight photoelectric sensors • Smart electricity meters	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals and kitchen faucets have effective water systems	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Solid Dense Concrete Blocks used for external and internal walls • Finished concrete floor • uPVC windows	237.65
Percentage savings in energy, water and embodied carbon						**40%**	**28%**	**41%**	

13. South Africa	Equites Park Riverfields – Sandvik Witfontein	New	Equites Park Riverfields is a mixed office and operations complex that incorporated resource-efficient technologies to lower the facility's operating costs and minimize its carbon footprint.	21 547.00	Preliminary EDGE Advanced Certificate	This building consists of: • Window to wall ratio is reduced • Insulation to the roof • Low-E (Low Emissivity) coated glazing • Internal areas has energy-saving lighting • Solar photovoltaics	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals and kitchen faucets have effective water systems	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Internal and external walls of common brick with plaster and paintwork to external and internal walls • Partitioning used for internal walls	531 t
Percentage savings in energy, water and embodied carbon						**71%**	**41%**	**21%**	
14. Ecuador	Edificio Matriz Banco ProCredit Ecuador	Retrofit	ProCredit Ecuador is the head office that used resource-efficient technologies to reduce the resource impact of construction (energy embodied in materials) in order to lower the carbon footprint of the project.	3 769.00	Final EDGE Advanced Certification	This building consists of: • External walls and roof have reflective paint • Internal and external areas have energy-saving lighting • Staircases and	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Kitchen faucets have	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning used for internal walls • The existing ceramic	40.1 t

						passages have lighting controls • Smart electricity meter • Solar photovoltaics	effective water systems	flooring is kept	
Percentage savings in energy, water and embodied carbon						**47%**	**33%**	**93%**	
15. El Salvador	INNOVALAB	Retrofit	Innovalab is an existing office building that incorporated resource-efficient technologies.	348.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External walls and roof have reflective paint • Variable refrigerant volume (VRV) cooling system • Energy-saving lighting • Occupancy sensors	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Showers have effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning used for internal walls • The existing flooring is kept	28.90
Percentage savings in energy, water and embodied carbon						**66%**	**42%**	**97%**	

16. India	Stallion Laboratories, Pvt. Ltd. (Unit II)	New	Stallion Laboratories, Pvt. Ltd., a new office building that incorporated resource-efficient technologies in order to receive a Final EDGE Advanced (Zero Carbon Ready) Certification.	10 800.00	Final EDGE Advanced (Zero Carbon Ready) Certification	This building consists of: • Window to wall ratio is reduced • Low-E coated glazing • A/C with Water Cooled Chiller • Efficient Boiler • Variable Speed Drives in AHU and Pumps • Internal and external areas have energy-saving lighting • Passages, sales area, common and external areas have occupancy sensors • Smart electricity meters • Solar photovoltaics	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • A recycling and black water treatment system.	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Autoclaved aerated concrete blocks used for internal walls • Stone tiles for floor finishes • Aluminium windows • Polyurethane insulation	342.60
Percentage savings in energy, water and embodied carbon						**100%**	**61%**	**40%**	

17. Kenya	The Cube	New	The Cube is a new office development that focusses on lighting efficiency, high performance glazing and solar photovoltaics, as well as sustainable waste management.	9 366.60	Preliminary EDGE Advanced Certificate	This building consists of: • External shading elements • High thermal performance glazing • Energy-saving lighting • Occupancy sensors • Solar photovoltaics	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Showers have effective water systems	This building consists of: • Concrete filler floor and roof slabs • Stone blocks used for external and internal walls • Finished concrete floors	133.78
Percentage savings in energy, water and embodied carbon						**41%**	**50%**	**21%**	

18. Peru	Grupo OL Head Office	New	Grupo OL is new office building constructed with energy and water saving measures to enhance the building's resource efficiency.	763.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Roof has reflective paint • High thermal performance glazing • Air conditioning with an air-cooled screw chiller • Internal and external spaces have energy-saving lighting	This building consists of: • Water closets have dual flush systems • Urinals have effective water systems	This building consists of: • Concrete filler floor and roof slabs with polystyrene blocks for the floors • In-situ reinforced concrete roof • Medium weight hollow concrete blocks for external and internal walls • In-situ reinforced concrete external walls • Partitioning used for internal walls	30.10
Percentage savings in energy, water and embodied carbon						**56%**	**49%**	**56%**	

19. Mexico	GRUPAK Corrugado Hidalgo – Oficinas	New	Grupak is a commercial development that used resource-efficient design and technologies to minimize the energy and water usage.	2 680.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • Roof has reflective paint • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal and external spaces have energy-saving lighting • Occupancy sensors	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • A recycling and black water treatment system.	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete and steel deck used for the roof • Medium weight concrete blocks used for internal walls • Partitioning used for internal walls	120.50
Percentage savings in energy, water and embodied carbon						**54%**	**59%**	**40%**	
20. Georgia	ProCredit Bank Georgia	Retrofit	ProCredit Bank Georgia is an existing commercial building that combined modern architectural designs with water, energy and material efficiency.	9 659.00	Final EDGE Advanced Certification	This building consists of: • External shading elements • Roof has insulation	This building consists of: • Bathrooms have low-flow faucets	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and	164.02

						• Low-E coated glazing • Spacing has a High Efficiency Condensing Boiler • Air Economizers is used during favourable outdoor conditions • Internal and external areas have energy-saving lighting • Staircases and passages have lighting controls • Bathrooms, closed cabins and conference rooms have occupancy sensors • Solar Photovoltaics	• Water closets have effective water flush systems • Kitchen faucets have effective water systems • Rainwater harvesting system	external walls are kept as is • The existing flooring is kept • The existing windows are kept	
Percentage savings in energy, water and embodied carbon						**44%**	**38%**	**92%**	

21. India	A.Shridhar Athens	New	A.Shridhar Athens is a new 13-storey mixed-use building that utilizes resource-efficient design technologies and features minimizing the environmental impact and reduce its carbon footprint.	23 235.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • High thermal performance glazing • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Bathrooms, closed cabins and conference rooms have occupancy sensors	This building consists of: • Bathrooms have low-flow faucets • Urinals have effective water systems • A recycling and black water treatment system.	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Autoclaved aerated concrete blocks used for external and internal walls	1 031.00
Percentage savings in energy, water and embodied carbon						**46%**	**51%**	**32%**	

22. Ecuador	Hotel Le Parc, Beyond the Stars	New	The Le Parc project is a new mixed-use development that utilizes resource-effective technologies and design features minimize its environmental impact and reduce its carbon footprint.	14 244.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • Insulation to the roof and external walls • High thermal performance glazing • Heat pump water generation system • Common and internal spaces have energy-saving lighting • External and common areas have lighting controls • Solar photovoltaics	This building consists of: • Showers have a low-flow system • Water closets have dual flush systems • Urinals have effective water systems • Aerators and auto shut-off faucets • Rainwater harvesting system	This building consists of: •In-situ reinforced concrete and steel deck used for the roof and floor slabs (permanent shuttering) • Polystyrene insulation in roof • Glass wool insulation in walls • Partitioning used for internal and external walls	424.00
Percentage savings in energy, water and embodied carbon						**48%**	**59%**	**35%**	

23. Costa Rica	Casa Carazo	New and Retrofit	Casa Carazo is a new and existing building development on a historic property. Green building elements was used for a sustainable development.	457.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • External shading elements • Insulation to the roof • Variable refrigerant flow (VRF) cooling system • Internal and external areas have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning with insulation is used for internal walls • The existing windows are kept • New steel-clad sandwich panels used for external walls • New light gauge steel cassette is used for the floor • New ferro cement is used for the roof	3.70
Percentage savings in energy, water and embodied carbon						**47%**	**21%**	**64%**	

24. Costa Rica	The Green Park Free Zone Office	New	The Green Park Free Zone consists of industrial and office spaces of 50,000m² making use of resource-efficient technologies and the use of renewable energy to meet operational savings associated with green building design.	248.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Insulation to the roof • Variable refrigerant flow (VRF) cooling system • Internal and external areas have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	This building consists of: •In-situ reinforced concrete and steel deck used for the floor slabs • Steel rafter roof construction with steel sheets • Insulation in walls • Partitioning used for internal walls • Cement fibre boards are used for external walls	2.30
Percentage savings in energy, water and embodied carbon						**48%**	**36%**	**49%**	

25. Bulgaria	ProCredit Bank Bulgaria Head Office	Retrofit	The Head Office of ProCredit Bank Bulgaria is an existing office building achieved EDGE Zero Carbon certification having an 100% offset of operational emissions and having at least 40% onsite energy savings compared to a base case building.	4 872.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Insulation to the roof and external walls • High thermal performance glazing • Energy-efficient air conditioning system • Common and internal spaces have energy-saving lighting • Occupancy sensors • Solar photovoltaics • Offsite renewable energy procurement • Carbon offsets	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • The existing flooring is kept • The existing windows are kept	463.30
Percentage savings in energy, water and embodied carbon						**50%**	**46%**	**94%**	

26. Indonesia	Gedung Pertamax PT Pertamina (Persero) RU VI Balongan	Retrofit	The Gedung Pertamax office building was built in 2009 committed to conserve natural resources in its operational and supporting activities by using resource-efficient technologies.	2 599.00	Final EDGE Certification	This building consists of: • Variable refrigerant flow (VRF) cooling system • Internal and external areas have energy-saving lighting.	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Cored bricks used for internal walls • Partitioning used for internal walls • The existing ceramic tile flooring is kept • The existing windows are kept	252.60
Percentage savings in energy, water and embodied carbon						**44%**	**36%**	**83%**	

27. Mexico	Oficinas FINSA Aguascalientes	New	FINSA is a new office development incorporating savings in energy and water to reduce the office's operating costs through resource-efficient design and technologies.	195.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Roof has reflective paint • Low-E coated glazing • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting • Closed cabins, bathrooms and conference rooms have occupancy sensors	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • In-situ reinforced concrete slabs • Concrete filler slab with polystyrene blocks for the roof • Precast concrete external wall panels • Cored bricks used for external and internal walls with plaster and paint • Nylon carpets and finished concrete flooring for floor finishes	10.10
Percentage savings in energy, water and embodied carbon						**45%**	**35%**	**52%**	

28. Macedonia	ProCredit Bank N. Macedonia Head Office	New	The ProCredit Group office building making use of resource-efficient technologies and features for a sustainable development	4 184.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Insulation to the roof and external walls • High thermal performance glazing • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Closed cabins, bathrooms and conference rooms have occupancy sensors • Solar photovoltaics • Ground source heat pump • Variable frequency	This building consists of: • Water closets have dual flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • In-situ reinforced concrete slabs •In-situ reinforced concrete roof • Autoclaved aerated concrete blocks used for external and internal walls • Insulation in walls • Partitioning used for internal walls • Vinyl tiles used for floor finishes	249.40

						drives in AHUs and speed drive pumps • Air economizers while there are favourable outdoor conditions • Sensible heat recovery from exhaust air			
Percentage savings in energy, water and embodied carbon						**73%**	**21%**	**35%**	
29. Indonesia	GM Office PT Pertamina (Persero) RU III Plaju	New	The General Manager's Office is a new office development that conserves natural resources to reduce the building's energy use by half and the building's water use.	840.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • External and internal spaces have energy-saving lighting • Solar photovoltaics	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete for the roof • Aluminium-clad sandwich external wall panels • Common bricks used for external and internal walls with	0.03

								plaster and paint	
Percentage savings in energy, water and embodied carbon						**50%**	**37%**	**43%**	
30. Colombia	Cámara de Comercio Santa Marta	New	The Chamber of Commerce's new resource-efficient office building consists of nine-storeys that is designed and built to make a minimal environmental impact.	6 748.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • External shading elements • Roof and external walls has reflective paint • External and internal spaces have energy-saving lighting • Solar energy system	This building consists of: • Water closets have dual flush systems • Urinals have effective water systems • Reduced water usage in the cooling towers	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete for the roof • Common bricks used for external and internal walls with plaster and paint • Finished concrete floor	98.50
Percentage savings in energy, water and embodied carbon						**47%**	**52%**	**33%**	

31. Mexico	Ufficio BJX	Retrofit	Ufficio Arquitectura y Mobiliario is an existing building that was converted into an office development in order to achieve EDGE Zero Carbon certification.	415.00	Final EDGE Certification	This building consists of: • Roof and external walls have reflective paint • External and internal spaces have energy-saving lighting • Solar energy system • Ceiling fans in the offices	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • The existing internal and external walls are kept as is • In-situ composite concrete and steel decks for the floor and roof	11.50
Percentage savings in energy, water and embodied carbon						**50%**	**23%**	**36%**	
32. Indonesia	HSSE Demo Room	New	HSSE Demo Room is a new office development constructed to conserve natural resources through implementing green features to reduce its energy and water usage by more than 50%, which will also save operational costs.	567.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • External and internal spaces have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems	This building consists of: • Controlled use of concrete for the slabs • Steel rafter roof construction with steel sheets • Aluminium-clad sandwich external wall panels	131.20

								• Common bricks used for external and internal walls with plaster and paint	
Percentage savings in energy, water and embodied carbon						**52%**	**55%**	**46%**	
33. Philippines	ArthaLand Century Pacific Tower	New	ArthaLand Century Pacific Tower received EDGE Zero Carbon certification having 100% offset of its operational emissions and 45% projected energy savings with 100% hydroelectric energy which is supplied by the Pantabangan Masiway Hydroelectric Plant.	77 428.00	Final EDGE Certification	This building consists of: • External shading elements • Roof has reflective paint • Insulation to the roof • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal and external spaces have energy-saving lighting • Occupancy sensors in	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Urinals have effective water systems • Rainwater harvesting system • A recycling and black water treatment system •	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete roof • Curtain walling used for external walls • Medium weight hollow concrete blocks used for internal walls • Partitioning used for internal walls • Finished concrete floor with stone tiles	1 288.90

						offices • Sensible heat recovery from exhaust air • Daylight photoelectric sensors for internal areas • Offsite renewable energy procurement	Condensate water recovery		
Percentage savings in energy, water and embodied carbon						**45%**	**64%**	**34%**	
34. Philippines	Climate Change Resilient Pilot Office	New	The Climate Change Resilient Pilot Office is a new office development using advanced systems and solutions to curb energy usage and nearly eliminate water usage in comparison to a typical building.	72.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Insulation to the roof and external walls • Operable windows with natural ventilation and no air conditioning • External and internal spaces have energy-	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Kitchen sinks have faucets for effective water systems • Rainwater harvesting system	This building consists of: • Concrete filler floor slabs • Timber rafter roof construction with steel sheets • Medium weight hollow concrete blocks used for external walls • Partitioning used for internal walls • Finished concrete floor•	1.10

						saving lighting • Staircases and passages have lighting controls • Ceiling fans in the offices	• A recycling and black water treatment system • Condensate water recovery	Aluminium windows	
Percentage savings in energy, water and embodied carbon						**61%**	**95%**	**79%**	
35. Ghana	Atlantic Tower	New	The Atlantic Tower is a new office building of 13-storeys that conserves energy and reduced water usage, while reducing their operational costs by 50%.	57 727.00	Final EDGE Certification	This building consists of: • External shading elements • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal and external spaces have energy-saving lighting • Occupancy sensors	This building consists of: • Showers have a low-flow system • Water closets have effective water flush systems • Urinals have effective water systems	This building consists of: • Concrete filler floor slabs • Concrete filler roof slab • Curtain walling used for external walls • Partitioning used for internal walls	282.20
Percentage savings in energy, water and embodied carbon						**46%**	**56%**	**49%**	

36. Jordan	King Hussein Business Park – Building Four	Retrofit	The King Hussein Business Park (KHBP) is an existing mixed-use development consisting of four-storeys designed to improve its conservation of natural resources and carbon emissions.	3 630.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Roof has reflective paint • Insulation to the roof • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Internal and external spaces have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is • Partitioning used for internal walls • The existing windows are kept	108.60
Percentage savings in energy, water and embodied carbon						**47%**	**44%**	**91%**	
37. Costa Rica	CCCR: Centro de Convenciones de Costa Rica	New	The CCCR: Centro de Convenciones de Costa Rica new office development that is resource-efficient to reduce energy consumption.	16 057.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Roof has	This building consists of: • Bathrooms and	This building consists of: • Hollow-core precast floor slabs • Steel rafter	188.70

						reflective paint • Insulation to the roof and external walls • Energy-efficient air conditioning with water-cooled chiller • Variable frequency drives in AHUs • Pumps with variable speed drives • External and internal spaces have energy-saving lighting • Occupancy sensors	kitchens have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems • Rainwater harvesting system	roof construction with steel sheets • Polymeric render on concrete blocks used for external walls • Medium weight hollow concrete blocks used for internal walls • Partitioning with insulation used for internal walls • Terrazzo tiles used for floor finishes	
Percentage savings in energy, water and embodied carbon						**49%**	**57%**	**46%**	

38. India	Office of the Tamil Nadu Infrastructure Fund	Retrofit	The Tamil Nadu Infrastructure Fund Management Corporation (TNIFMC) is existing office building using green features to reduce the embodied energy in materials.	687.00	Final EDGE Certification	This building consists of: • External shading elements • Roof has reflective paint • Insulation to the roof • Variable refrigerant volume (VRV) cooling system • Internal and external spaces have energy-saving lighting	This building consists of: • Bathrooms and kitchens have low-flow faucets • Water closets have dual flush systems • Urinals have effective water systems	This building consists of: • Steel rafter roof construction with aluminium sheets • Autoclaved aerated concrete blocks used for external walls • Partitioning used for internal walls	107.20
Percentage savings in energy, water and embodied carbon						**74%**	**44%**	**39%**	
39. Indonesia	KC Makassar	New	The Makassar Branch Office Building is a new office building consisting of four-storeys designed to maximize natural light and air circulation, using practical solutions for energy and cost savings, as well as environmentally	1 076.00	Preliminary EDGE Certificate	This building consists of: • Variable refrigerant flow (VRF) cooling system with co-efficient of performance • Internal and external areas have energy-	This building consists of: • Water closets have dual flush systems • Urinals have effective water systems	This building consists of: • Autoclaved aerated concrete blocks used for external and internal walls • Partitioning used for internal walls	98.50

			friendly construction materials.			saving lighting • Open offices have occupancy sensors	• Kitchen sinks have faucets for effective water systems		
Percentage savings in energy, water and embodied carbon						**52%**	**32%**	**60%**	
40. Indonesia	Working Room Data Center Serpong	New	The Working Room Data Center is a new office development designed to be resource-efficient and green, conserving up to 75% in water use and limits energy usage.	11 441.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • External shading elements • Low-E (Low Emissivity) coated glazing • Energy-efficient air conditioning with water cooled chiller • Internal areas have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Rainwater harvesting system • A recycling and black water treatment system • Condensate water recovery	This building consists of: • Curtain walling used for external walls • Autoclaved aerated concrete blocks used for internal walls • Partitioning used for internal walls • Finished concrete floor	505.4 t
Percentage savings in energy, water and embodied carbon						**43%**	**75%**	**30%**	

41. China	Johnson Controls HQ Asia Pacific	New	The Johnson Controls is a new office development consisting of five-storeys of 54,000m² designed to be resource-efficient and sustainable.	44 934.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Insulation to the roof and external walls • High thermal performance glazing • Energy-efficient air conditioning with water-cooled chiller • Variable frequency drives in AHUs • Pumps with variable speed drives • Sensible heat recovery from exhaust air • High efficiency condensing boiler for space heating • Air economizers while there is favourable	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective water flush systems • Rainwater harvesting system • A recycling and black water treatment system	This building consists of: • In-situ reinforced concrete slabs with pulverized fly ash • In-situ reinforced concrete roof with pulverized fly ash • Polystyrene insulation for roof • Aluminium profile cladding external walls • Mineral wool insulation in walls • Nylon carpets and stone tiles used for floor finishes	1 069.00

						outdoor conditions • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Occupancy sensors • Daylight photoelectric sensors for internal areas • Solar photovoltaics.			
Percentage savings in energy, water and embodied carbon						45%	42%	21%	

42. India	Abhikalpan Office	New	The Abhikalpan Office is a 573m² new office development using building's green design solutions to contribute to energy, water or embodied energy in materials savings.	573.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • Roof has reflective paint • Insulation to the roof• High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • Heat recovery from exhaust air • Internal and external spaces have energy-saving lighting • Staircases and passages have lighting controls • Solar photovoltaics	This building consists of: • Bathrooms and kitchens have low-flow faucets • Rainwater harvesting system • A recycling and black water treatment system	This building consists of: • Autoclaved aerated concrete blocks used for external walls • Polystyrene insulation for roof • Stone and ceramic tiles used for floor finishes • uPVC windows	71.00
Percentage savings in energy, water and embodied carbon						**68%**	**83%**	**28%**	

43. Lebanon	Tohme Rizk Office Building	Retrofit	The Tohme Rizk Office Building is an existing office building that uses energy-efficient solutions and existing building elements to reduce embodied energy for a reduced carbon footprint and a sustainable construction project.	930.00	Final EDGE Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Air conditioning with air-cooled chiller and a high COP • Variable speed drive pumps • Internal areas has energy-saving lighting	This building consists of: • Bathrooms and kitchens have low-flow faucets • Water closets have dual flush systems	This building consists of: • Concrete filler floor slabs • Solid dense concrete blocks used for external and internal walls	21.00
Percentage savings in energy, water and embodied carbon						**41%**	**29%**	**34%**	
44. Philippines	NEO Portfolio	Retrofit	The NEO portfolio is an existing development that consists of seven office building projects which covers 289 000m². The inputs of construction materials are minimized in order to reduce the projects' carbon footprints with 1 555 tons of CO² per year.	289 375.60	Preliminary EDGE Advanced Certificate	This building consists of: • Window to wall ratio is reduced • External shading elements • Insulation to the roof and external walls	This building consists of: • Bathrooms have low-flow faucets • Water closets have effective	This building consists of: • The existing floor and roof construction are kept as is • The existing internal and external walls are kept as is	1 555.27

						• High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Closed cabins, bathrooms and conference rooms have occupancy sensors • Offsite Renewable Energy Procurement • Smart electricity meters	water flush systems • Urinals have effective water systems • Rainwater harvesting system • Condensate water recovery	• The existing flooring is kept • The existing windows are kept	
Percentage savings in energy, water and embodied carbon						**43%**	**41%**	**94%**	

45. Indonesia	Fuel Terminal Tanjung Gerem	Retrofit	Fuel Terminal Tanjung Gerem is an existing office building constructed in 1994, it was refurbished to obtain energy, water and embodied energy savings in order to save more than 76 tons of CO^2 emissions per year.	893.56	Final EDGE Advanced Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • Variable refrigerant volume (VRV) cooling system • Internal spaces have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have efficient flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete for the roof • Common bricks used for external walls with plaster and paint • Partitioning used for internal walls • Parquet and wooden blocks used for floor finishes	76.35
Percentage savings in energy, water and embodied carbon						**44%**	**43%**	**34%**	
46. Nigeria	Stanbic IBTC Bank Idejo Branch	New	The Stanbic IBTC Bank Idejo Branch is a new office building of 985.615m², sustainable efficiency measures were implemented to promote sustainability and ensure that the building is eco-	1 044.41	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • Roof has reflective paint • Variable refrigerant	This building consists of: • Bathrooms have low-flow faucets • Water closets have	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete for the roof	35.39

			friendly creating a balance between the façade's facial aesthetic and the green measures' effectiveness. .			volume (VRV) cooling system • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Closed cabins, bathrooms and conference rooms have occupancy sensors	efficient flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	• Steel rafter roof construction with aluminium sheets • Medium weight hollow concrete blocks used for internal and external walls • Aluminium profile cladding external walls • Partitioning used for internal walls	
Percentage savings in energy, water and embodied carbon						**20%**	**22%**	**45%**	

47. Paraguay	Oficinas Dumot Construcciones	New	The Dumot Construcciones Company is a new office development with extensive views to the outside in order to increase natural lighting, reduce energy consumption and use of open vegetated spaces for dining rooms, training areas and common uses to promote a healthy environment.	636.30	Final EDGE Advanced Certification	This building consists of: • Window to wall ratio is reduced • External shading elements • External walls have reflective paint • Insulation to the roof and external walls • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting	This building consists of: • Bathrooms have low-flow faucets • Water closets have efficient flush systems • Kitchen sinks have faucets for effective water systems	This building consists of: • In-situ reinforced concrete and steel deck slabs • In-situ reinforced concrete and steel deck slab for the roof • Precast concrete external wall panels • Vinyl tiles and finished concrete flooring for floor finishes • Aluminium windows	5.59
Percentage savings in energy, water and embodied carbon						**49%**	**22%**	**39%**	

48. Vietnam	Ho Chi Minh City Innovation Start-Up Hub	New	Ho Chi Minh City Innovation Start-Up Hub is a new office development consisting of 8-storeys that incorporates modern technologies to minimize its energy and water consumption for a more sustainable construction project and reduced carbon footprint.	9 491.00	Preliminary EDGE Certificate	This building consists of: • Insulation to the roof and external walls • Low-E coated glazing • Variable refrigerant volume (VRV) cooling system • Internal and external areas have energy-saving lighting • Internal areas have daylight photoelectric sensors • Smart electricity meters• Solar photovoltaics	This building consists of: • Bathrooms have low-flow faucets • Water closets have efficient flush systems • Urinals have effective water systems • Kitchen sinks have faucets for effective water systems	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete roof • Cement Fibre Boards used for external walls • Autoclaved aerated concrete blocks used for external and internal walls • In-situ reinforced concrete walls used for internal walls • Finished concrete floor	271.50
Percentage savings in energy, water and embodied carbon						**28%**	**40%**	**27%**	

49. Morocco	Prism	New	Prism is a new mixed-use development consisting of 6 000m² of modern and flexible office spaces, consisting of materials with low pollutant emissions and reduced energy usage.	8 520.00	Preliminary EDGE Advanced Certificate	This building consists of: • External shading elements • Insulation to the roof and external walls • High thermal performance glazing • Variable refrigerant volume (VRV) cooling system • External and internal spaces have energy-saving lighting • Staircases and passages have lighting controls • Open and closed offices, bathrooms and conference rooms have occupancy sensors	This building consists of: • Bathrooms and kitchens have low-flow faucets • Water closets have efficient flush systems	This building consists of: • In-situ reinforced concrete slabs • In-situ reinforced concrete roof • Curtain walling used for external walls • Cored bricks used for internal walls with plaster and paint • Nylon carpets and finished concrete flooring for floor finishes • Aluminium windows	227.20

						• Internal areas have daylight photoelectric sensors • Consumption based electricity meters			
Percentage savings in energy, water and embodied carbon						**40%**	**47%**	**21%**	
50.Gabon	FGIS Headquarters	New	FGIS Headquarters-La Baie des Rois is a new office development is constructed to reduce its carbon emissions, minimize energy consumption, and save water.	4 638.00	Preliminary EDGE Certificate	This building consists of: • Window to wall ratio is reduced • External walls have reflective paint • External shading elements • Insulation to the external walls • Efficiency of glazing • Efficient Cooling System with Variable Speed Drives • Air Economizers	This building consists of: • Showers have an effective water system • Water closets have efficient flush systems in all bathrooms, as well as public bathrooms • Urinals have effective water systems	This building consists of: • Concrete filler slab with polystyrene blocks for the floor slabs • Concrete filler slab with polystyrene blocks for the roof • Precast concrete external wall panels • Partitioning used for external and internal walls • Aluminium windows	24.28

							• Kitchen sinks and public bathrooms have faucets for effective water systems • Smart water meters		
Percentage savings in energy, water and embodied carbon						**22%**	**21%**	**25%**	

Source: (EDGE, 2023)