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Green Buildings as an Accelerator in Climate Change Mitigation and Air Quality Improvement

Ofhani Mukwevho, Trynos Gumbo, Walter Musakwa

(Ofhani Mukwevho, Urban and Regional Planning Department, University of Johannesburg, Johannesburg, South Africa, omukwevho3@gmail.com)
(Prof Trynos Gumbo, Smart and Sustainable Cities and Regions Research Group, Urban and Regional Planning Department, University of Johannesburg, Johannesburg, South Africa, tgumbo@uj.ac.za)
(Prof Walter Musakwa, Department of Geography Environmental Management Energy Studies, University of Johannesburg, Johannesburg, South Africa, wmusakwa@uj.ac.za)

1 ABSTRACT

The world is changing quickly in all spheres, including, but not limited to, technology, cities, finances, society, and the environment. Regarding the latter, the prevailing themes or debated subjects have been the ozone layer, air quality, greenhouse gases, and climate change. As a result, there is now an even greater need to address present and potential climate change concerns. These initiatives are essential if society is to contribute to the development of cities and communities that are efficient, interconnected, and sustainable. The advent and evolution of green buildings throughout the 1990s, which saw the creation of the first-ever sustainability standard and rating system for the built environment, were regarded as turning points because they could be embraced as one of the methods employed to control the deteriorating climate and air quality while enhancing our infrastructure. To aid in the development of the nation's infrastructure, South Africa has its rating system known as the Green Star SA through the Green Building Council of South Africa (GBCSA). In addition to looking at how green buildings have been acting as a catalyst in reducing the challenge of the change in climate in the region, this paper will also look at how the overall commercial green building network in Gauteng can help improve the region's air quality, which tends to be on a "moderate" level according to the World Health Organization (WHO). Reviewing present frameworks and legislation concerning climate change, air quality, and green buildings was the strategy, moving from a global to a local level. The research also examines data from 180 case studies of green buildings in the Gauteng region, which were taken from the GBCSA archives. Observations in 4 buildings for 4 months and a building occupant survey in one of the 4 buildings were used to do additional research on the 180 case studies. According to the research findings, the government in the Gauteng region lacks the motivation to establish and enforce green building policies. This is especially evident given that more than 80% of the region's green buildings are built and owned by the private sector. According to the report, green buildings in Gauteng can accelerate efforts to mitigate climate change and improve air quality by using less energy, incorporating renewable energy sources, enhancing interior air quality, and lowering urban heat islands. Green buildings also have a positive socio-economic impact, creating new jobs and skills, promoting diversity and growing the local economy. The benefits of green building cannot be overlooked. Therefore, the study recommends that the Gauteng government review and develop robust policies to increase investment in green buildings.

Keywords: Climate change, green buildings, air quality improvement, greenhouse gases, Gauteng

2 INTRODUCTION

The primary drivers of climate change and poor air quality are several, including human activities such as burning fossil fuels, transportation activities, agriculture and industrial processes. A greater portion of the fossil fuel burnt is for energy production and according to (Ritchie, Roser and Rosado, 2022) buildings are responsible for more than 40% of global energy used, and as much as one-third of global greenhouse gas emissions. The impacts of climate change are quite vast and can have detrimental effects on both our natural systems and human societies ranging from health problems, economic impacts, rising temperatures etc. According to the IPCC (2020), Africa is one of the most vulnerable continents to climate change and climate variability, a situation aggravated by the interaction of „multiple stresses“, occurring at various levels and low adaptive capacity. Hence it is not surprising that the challenges stated are not unique to Gauteng as a region and both climate change and air quality have impacted the region and are most likely to worsen in the future, thus there is a need to mitigate the effects caused to help improve the natural systems and lives of the society in the region. The relationship between buildings, climate change and air quality comes about as these buildings lead to the intensification of climate change and poor air quality and the effects they cause. Suzuki (2019) stated that the current rate is which the population is growing, and the expectation for 2050 is

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10 billion people, of which 70% will be occupying space in cities. Subsequently, there will be more construction of buildings to accommodate the needs of these people. This does however pose a threat as stated previously in terms of the rise of emissions of greenhouse gases and energy demand from buildings. The problem is that this growth facilitates the acceleration of climate change and poor air quality hence the need to find ways to accommodate the needs of the current without compromising future generations. Indeed, the issue of climate change and air quality is rather complex, requiring a comprehensive approach that includes mitigation (reducing greenhouse gas emissions) and adaptation (building resilient systems & and infrastructures while adapting to change) (Howard-Grenville et al, 2014). The paper will look into how green buildings in the Gauteng region can act as a partial solution to address and accelerate the much-needed change in mitigating climate change and improving poor air quality. He (2019) suggested that green buildings can help by transitioning to renewable energy, promoting energy & and water efficiency, and adopting sustainable practices. hence it is quite important to understand the developed frameworks and policies developed at local, national and global levels about green building, climate change and air quality.

3 CONCEPTUAL SYNOPSIS

The concept of green buildings and its importance in society can be traced back to the early 1990s when the Building Research Establishment (BRE) developed the world's first sustainability standard and rating system/tool for the built environment known as the Building Research Establishment Environmental Assessment Method (BREEAM) (Doan et al, 2017). The development of green buildings internationally can be attributed to the concept of sustainable development in the period of the 1980s-1990s when international conferences were held to address the growing challenges of the society of climate change and global warming. There have been many conferences held to address climate change and air quality but some of the crucial ones which were also key turning points were:

- The 1987 World Commission on Environment and Development (WCED) known as the Brundtland Commission/Report led to the formal and commonly accepted definition of sustainable development (Brundtland, 1987).
- The United Nations Conference on Environment and Development also known as the Rio Earth Summit, or Rio Summit 1992, where member states of the Un cooperated on issues relating to sustainability, suggesting that this was an issue far greater for individual member states to handle which led to another conference in 1997. (Grubb et al, 2019)
- The Kyoto Protocol is an international treaty which came about as an extension of the 1992 United Nations Framework Convention on Climate Change (UNFCCC) committing member states to reduce greenhouse gas emissions due to impacts on global warming. (United Nations Climate Change, 2019)
- COP 27, the reaffirmation of commitment to limit the global temperature to 1.5 degrees Celsius above pre-industrial levels, in particular with Africa announcing the African Alliance for Sustainable Cities and the Built Environment. (ICLEI, 2022)

Frameworks, international treaties, and policies of this nature and those related which couldn't be covered in this scope have popularized the movement of green buildings and the development of other sustainable and building rating tools globally such as the Leadership in Energy and Environmental Design (LEED) by the United States of America Green building council, the Green Star Australia by the Green building council of Australia (Doan et al, 2017). The latter is the one on which the South African Green Building Council (GBCSA) rating system the Green Star SA is based and changed to accommodate various local conditions. According to Zuo and Zhao (2014), green buildings through their design and construction practices would significantly reduce and eliminate greenhouse gases which are the ultimate cause of climate change and poor air quality through sustainable site planning (efficient design), safeguarding water and water efficiency, energy efficiency and use of renewable energy, the conversation of material and resources, and improved indoor environmental quality. Even though there are international frameworks and policies that exist and act as standards from which countries can work, the development of green building varies from country to country due to many aspects such as the advancement of the country, governance, socio-economic level etc. In South Africa, the Green Building Council of South Africa is the organization responsible for advocacy, training and certification which functions through its membership community comprised of government,

private and educational stakeholders. The GBCSA (2021) reported in their integrated annual report that South Africa had around 740 certified Green Star buildings from the start of the organisation in 2009. Furthermore, the South African government through the Department of Public Works developed the Green Building Framework to help accelerate the movement of green buildings in the country especially with government infrastructure with the intent that these buildings will save water, and energy and lessen the emission of greenhouse gas.

4 LOCAL AND INTERNATIONAL EXPERIENCES OF GREEN BUILDINGS DEVELOPMENT

Through case studies, one can gain an understanding and insight into the realistic perspective of the theoretical work. South Africa (Gauteng) is advancing in their efforts to mitigate climate change and improve air quality through green buildings as stated that already over 700 green buildings have been developed however lessons can be learned from different regions in the world to understand their use of green building in curbing the challenge of climate change and poor air quality. To gain a better perspective and overall scope of the work of green buildings a sample of three case studies was randomly selected from Africa, Europe and Asia which represented developing (Africa, Ghana- Accra), transitional (Europe, Poland-Warsaw) and developed (Asia, Singapore-Singapore) economics respectively. The reason behind choosing the capitals is that most of the green building development advances and implementation of policies and frameworks to mitigate climate change occur in those cities. What was common in all these regions and considered pertinent is the issue of reducing energy consumption (greenhouse gases), meeting the international climate targets of the year 2050, and achieving most of the 2030 sustainable development goals (SDGs). From a local stand-point Gauteng as a region can learn and adopt various lessons from these three regions, the case studies showed that well-organized and competent urban governance is essential through the collaboration of the public and private entities to develop and efficient pipeline and implement green building policies that can help improve climate change and air quality. Another lesson was the need to start developing green buildings on a residential level as over 90% of green buildings in regions are from the commercial sector, hence the buy-in of residents is crucial in understanding the implication of climate change and air quality to the livelihoods, hence the sooner they jump onto the green building wagon these could improve their lives, especially from a health and economic stance.

5 METHODS AND MATERIALS

The research work done in the paper aims to give an understanding of how green buildings in the region of Gauteng can accelerate the mitigation of climate change and the improvement of air quality. The topic of climate change, air quality and green buildings is quite broad and requires thorough investigation, so to help prove the hypothesis of the study if indeed green buildings can reduce greenhouse gases which led to climate change and poor air quality factual and reliable data is crucial which can be obtained through quantitative research as this generates factual, reliable outcomes of the data that can be used to generalize larger quantity of the data (Steckler et al, 1992). Furthermore, the qualitative approach will be taken to gain insights from industry experts which can produce rich, in-depth validity on the basis of experience of how green buildings have an impact on accelerating climate change mitigation and building occupants who experience these green buildings on a frequent use basis. For the quantitative part of the study, the data was collected from 180 green building case studies files in Gauteng from the GBCSA archives and analysed through Python & and Google Data Studio for visualization. From the 180 case studies, 4 buildings were chosen for further actual in-person observations and investigation by the research over a period of 4 months wherein a building occupant survey was conducted through the BUS Occupant methodology in one of the buildings with 55 participants and yielded results of both quantitative & qualitative nature. For the qualitative part of the research 10 industry experts were interviewed through a semi-structured interview via Zoom and Microsft Teams, then analysed through the transcription software Otter which helped identify themes and topics within the conversations. The reason behind the use of semi-structured interviews assisted with open-ended data, explore the participants' thoughts, feelings and beliefs and help delve into their personal ideologies of climate change, air quality and green buildings (DeJonckheere and Vaughn, 2019). This was quite crucial as climate change as a topic has had critics in terms of whether we are really close to reaching the global warming levels of 1.5 degrees Celsius or not.

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6 FINDINGS

This section of the paper discusses the findings and results of the hypothesis of green buildings acting as an accelerator in climate change mitigation and air quality improvement. These findings and results outlined here will help give an understanding of the general outlook of green buildings in Gauteng from the 180 case studies sample, furthermore, two aspects of how green buildings can contribute to combating climate change and air quality are energy efficiency & and renewable energy integration and water conversation. The challenges encountered by the green building movement for climate change and air quality improvement will be explored to give a more in-depth understanding of the topic.

6.1 Green buildings in the region of Gauteng, South Africa

The hotspots for green building development in South Africa are the Western Cape, Kwazulu-Natal and Gauteng with the latter being a leader in terms of the number of certified commercial green buildings in the country. The research discovered that a large portion of green buildings developed in Gauteng is concentrated in the City of Johannesburg, particularly in the Northern Subrburb of Sandton City. The reason behind this was the fact that Sandton is the economic hub of the country which houses many international and local corporations as well as the Johannesburg Stock Exchange. From the interviews industry experts indicated that such corporations are seeking the use of green buildings as a way to align with their environment, social and governance strategies. Some industry experts criticised the reasons why developers and investors build green buildings as just a way to just tick box exercises to meet environmental regulations such as carbon tax emissions and keep regulators and the government away. Regardless of what the motive might be at the moment, it becomes less important as these green buildings are contributing to the change in the climate and air quality. From the research, it was recorded that of the 180 case studies more than 80% were developed by the private sector regardless of whether the government is an investor in the GBCSA and even a custodian of the Green Building Framework and Policy. In the next section of the paper, two main topics are covered which relate to water and energy conservation and efficiency techniques and how they were implemented in the 180 case studies while further looking at how they help mitigate climate change and poor air.

6.2 Adoption of Water Conservation and Efficiency Techniques

Conversations with regard to water in green buildings are related to water efficiency in the planned management of water to prevent wastage, overuse and exploitation of this precious resource. It should be understood however that water efficiency and conservation shouldn't be achieved at the expense of building occupants not using water comfortably. Well-designed green buildings are key in achieving water efficiency while still providing comfort to occupants, In one of the 4 buildings observed it was noted that the particular green building could conserve 0.3m^3 of water usage per annum as compared to a non-green star sa certified building. The Green Star SA awards points of certification out of 10 categories depending on the key features and category that particular green building focused on. The word cloud in (Figure 1), was extracted from the results of the 180 case studies, indicating that water was a key category for green building developers in the Gauteng region. Such just alludes to the fact that great efforts and measures are emphasized in terms of water conservation and efficiency techniques within the majority of the green buildings.

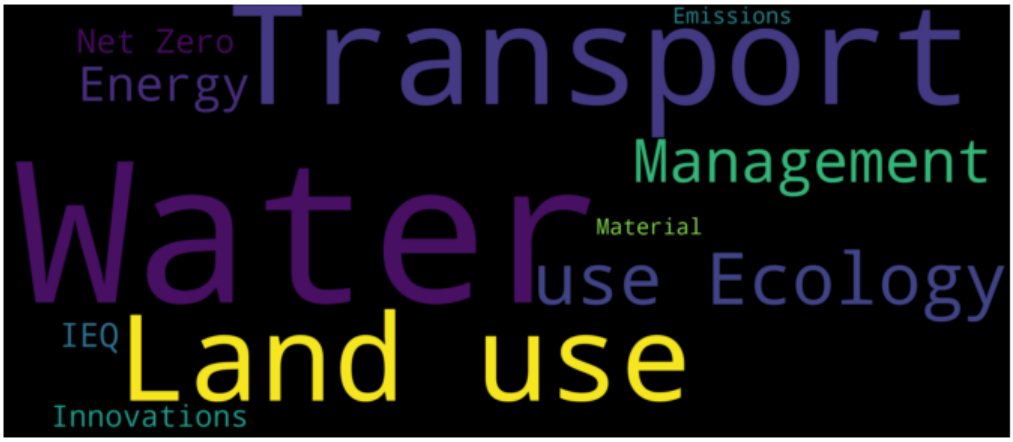

Fig. 1: Green Star SA category ranking on of 180 case studies. (Source: Author, 2021)

It is thus important to understand the measures that are deployed in green buildings for water conservation and efficiency as it is clear that it is an important and crucial category to measure the certification of green buildings. The first way is through water recycling and repurposing measures, the second is through water-efficient plumbing features and the last by irrigation and landscaping measures.

6.2.1 Water recycling and repurposing measures in Gauteng green buildings

The three ways in which green buildings in Gauteng have been adopted can either be any of these three methods, greywater harvesting, rainwater harvesting and blackwater system treatment, but of the three the latter is a rare and unique case which was notably deployed on one building due to being expensive in terms of operations. The rainwater and greywater are harvested from the rain through different channels on the rooftops of buildings and taken to the rainwater tank, while the greywater is harvested from showers, bathroom basins and other sources of this form. Once the greywater has gone through the treatment and filtration process it is usually stored in tanks located in the basements of buildings and supplemented with the harvested rainwater, which then will be used for WCs, urinal flushings and irrigation systems.

6.2.2 Water-efficient plumbing fixtures

Industry experts noted that the reason why the water category could be the leading category would highly be because of this particular feature of green buildings as it is the cheapest of all conservation techniques and strategies, which is low-flow plumbing from installation, operations and maintenance cost.

Fig. 2: Ultra-Low Flow plumbing fixtures (Source: Author, 2021)

All green-certified buildings will generally deploy low-flow fixtures and supplement them with either rainwater or greywater harvesting systems depending on the financial capability of the developer, these efficient water fitting as in Figure 2 reduce the use of potable water. Through the study, the paper found that a building with a rating of 6 Stars of the Green Star SA managed to save 0.52L/day/m2 of water.

6.2.3 Irrigation and Landscaping Measures

Landscape irrigation is another part of the building that consumes large amounts of water, which is why it is very important to reduce the amount of potable water used there. One of the green buildings from the case studies indicated that they could reduce 90% of potable water used for landscape irrigation, and this was achieved in collaboration with processed grey and rainwater to water the plants rather than using potable water.

6.2.4 Water Management Practices, Climate Change and Air Quality

The understanding is that by reducing water demand and promoting conservation, green buildings help address water scarcity issues exacerbated by climate change. It is without a doubt that water conservation and efficiency is a key performance category in the measurability of green buildings due to it being quantifiable in how it can save water usage and then recorded with the building‘s management systems

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which are relevant for the developer and owners from an economic stance as they tend to save on utility bills in a long term run. Therefore the use of water management practices as a feature of green buildings can directly impact the conservation of water resources, enhance resilience to drought and aid sustainable water usage in a changing climate. These techniques can further indirectly help improve air quality and can help minimise water-related pollutants and air pollution from wastewater treatment processes.

6.3 Renewable energy integration, energy efficiency and greenhouse gas emission mitigation

There are various techniques, methods and technologies that have been developed to achieve energy efficiency and reduction of greenhouse gas emissions such as the use of solar energy. Green buildings will tend to incorporate measures such as solar energy to attain their status of being a sustainable building. Investigation into these techniques is crucial in understanding how they help curb climate change and improve air quality, and which in particular have been implemented in green buildings around the Gauteng region.

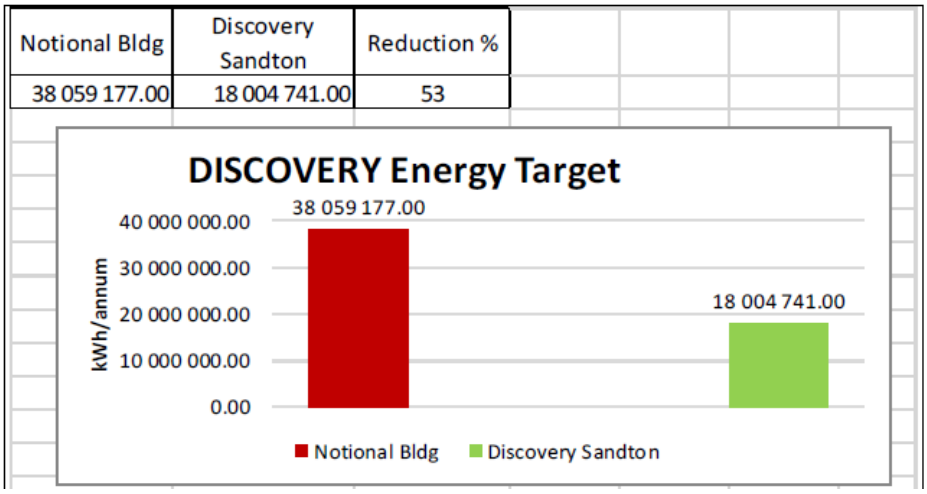

Fig. 3: Projected annual energy consumption (kWh/annum) for Discovery Limited (Source: Discovery Limited, 2017)

(Figure 3) has projected the annual consumption of energy for one of the four green buildings evaluated in the region where the building manager indicated that their energy target was 53% less compared to a SANS 10400 non-certified building (Notional building). It is quite clear that green buildings have the capability of saving and conserving energy which part is what is being investigated through the direct and indirect techniques developed.

6.3.1 Direct energy-saving and greenhouse gas emission reduction techniques

These kinds of techniques and strategies are built-in within green buildings, which includes either technology installed to help conserve energy such as smart lights or through methods adopted in the design and construction of the building. There are quite a few of these measures which include but are not limited to sustainable construction, efficient lighting & and occupancy sensors, HVAC systems & and smart metering, a passive design, solar energy etc. For the purposes of this research paper, only the latter two will be discussed in-depth. Sustainable construction is building through the use of renewable and recyclable materials while minimising water and energy while making sure the waste products is also minimal as the harnessing of the building material such as tree further worsens climate change. Efficient lighting and occupancy sensor requires the cooperation of building occupants through their behaviours.

In (figure 4) a green building that incorporated the passive design approach of saving energy is seen. Passive design is wherein the buildings' architectural features take advantage of local climatic resources to provide an indoor environment that is as comfortable as possible while saving energy that would have been used to provide the indoor environment quality. Through the industry experts, it was noted that the most favoured method in energy conserving and saving strategies was the passive design and more than 60% of the 180 case studies used this method due to the low cost involved in construction and maintenance. Furthermore, the consultant who worked to design the green building in (figure 4) stated that the vertical panels shift with the direction of the sunlight. What these panels help with is daylight harvesting which allows the natural light to be infused into the building thus reducing the need for excessive artificial light and heat from the HVAC.

The building evaluation survey of the 55 occupants of this building does indeed substantiate this notion. The section on occupants' overall temperature comfortability indicates that their working condition was fairly good due to the proper passive design in supplication of the HVAC system.

Fig. 4: High-performance facades (Source: Author, 2021)

Fig. 5: Side view of Photovoltaic solar panels (Source: GLH Architects, 2011)

The building in (figure 5) was the first building to be awarded 6 Stars Green Star SA certification in Africa, which recognizes world leadership standards and the highest rating a building can obtain through the Green Star SA rating system. This building not only achieved this feat but achieved a status for net-positive ecology and net-zero carbon. Essentially this is the certification of projects that go beyond the partial reductions recognized in the current GBCSA tools and have taken the initiative to reach the endpoint of completely neutralizing or positively redressing their impacts (GBCSA, 2017). For this building, the net positive ecology was in recognition of the increasing pilot-level 1: site ecology - brownfield site, while the net zero carbon was a result of the hybrid use of the passive design method discussed previously and the renewable solar energy technology (figure 5). The building has 292 solar photovoltaic panels which deliver 230kWh of energy to the building, the building manager stated that this was more than double what the building required to function at full capacity, and the excess energy produced was fed back into the rest of the buildings of this company's campus.

6.3.2 Indirect energy-saving and greenhouse gas emission reduction techniques

The previous section discussed direct energy conservation methods applied in the construction and functioning of green buildings, the industry experts indicated that green buildings shouldn't be viewed from a segmented view as they are but rather from a holistic approach. Yudelson (2009) cited that green building forms part of an eco-system in the development of sustainable cities and communities hence the understanding of the external factor that in-directly affects green buildings can't be ignored. The reason why these methods are important is that they are particularly linked to the reduction and curbing of greenhouse gases which directly affect climate change and air quality. The location of where a green building is

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developed is one of the in-direct strategies as we need to understand if this has an ecological impact on the environment, the other is transportation activities around the green building and how building occupants commute to these green buildings which is the strategy to be discussed. Transport is one of the categories 10 categories used in the Green Star SA rating tool as can be seen in (figure 1) hence the need to discuss it, and due to the fact that a white paper by the South African National Climate Change Response Policy identified that the transport sector is a significant contributor to greenhouses gases, the paper said the transport industry accounted for 70% of energy use and 38% of the region's emissions.

Fig. 6: Bicycle and Electric car charging stations (Source: Author, 2021)

The images in (figure 6) were initiatives from one green building that recognized that there is a need to involve the building occupants in building a sustainable community mitigating climate change and improving air quality by reducing greenhouse gases emitted by the vehicles used by occupants. The building manager indicated that only 10% of the occupants used electric vehicles and would use the facilities hence they provide bicycle stations as well for those occupants who can't afford electric vehicles, while for occupants who didn't have both electric vehicles or are farther away from the building and couldn't use bicycles carpooling was suggested as a way to reduce the vehicles on site.

6.3.3 Energy management practices, climate change and air quality

The use of energy-efficient designs and integration of renewable energy sources in green buildings around Gauteng was highlighted clearly. South Africa is still very reliant on the use of fossil fuels for energy sources but yet they still have challenges in this sector as can be seen through the load-shedding problem the country is facing. The various green buildings showed that the incorporation of efficient energy design such as passive design can help reduce the energy required to power and sustain buildings and harness renewable energy sources like the solar system adopted in one building which was able to produce surplus energy. Then thinking of a greater scale if all buildings were on this scale of green buildings it would definitely have an impact not only in the reduction of greenhouse gas emissions and meeting the goals of the country but also in providing an opportunity to reduce the energy challenges of the country.

6.4 Challenges in the Development of green buildings in Gauteng

The growing pressures of mitigating climate change and improving air quality to make sure that the global warming level doesn't reach 1.5 degrees Celsius have pushed South Africa to be one of the key players in green buildings as they try and adopt these buildings as a means to mitigate these challenges. The certification of over 740 buildings is a clear indication of the commitment to these efforts. As stated previously Gauteng is the top hot spot for green buildings and the largest contributing city in terms of greenhouse gas emissions. In sections 6.2 and 6.3, the paper outlined the benefits of green buildings and how they can mitigate climate change and improve air quality in Gauteng there are however challenges in the development and movement of green buildings that shouldn't be ignored as they can hinder their widespread adoption. The capital costs involved in green building development are quite high compared to building using conventional methods, in other instances, it might be operational costs which can be a problem. In one of the buildings investigated the building manager said that the cost of running the greywater system was

quite high and not viable to the point where it was turned off and not operational as the benefits could only be seen in the long term. Another issue is the lack of awareness from both the public and industry professionals which can be attributed to not being informed or not having the willingness to change from conventional ways of doing things. The industry experts indicated that the practice of implementing green buildings as a rating and tick box exercise was present in many property owners or developers as they just wanted to meet the minimum required standards but didn't have any ambitions to be innovative and implement different ways of building green which meets international standards. Last but not least was the implementation of the objectives within the various frameworks and policies developed in South Africa, it can be noted that such was affected by political challenges and a lack of stakeholder engagement in the development of green buildings

7 CONCLUSIONS AND RECOMMENDATIONS

Through the research, we came to understand that buildings generally consume a substantial amount of water and energy which directly influences water scarcity and the emission of greenhouse gases in the region of Gauteng. These resources in turn directly influence the contribution to climate change levels and poor air quality if not handled appropriately. Hence the hypothesis of the research was to investigate if green buildings had a positive impact by acting as an accelerator in climate change mitigation and air quality improvement within the region of Gauteng, South Africa. After careful investigation of both quantitative and qualitative findings and results, the hypothesis of the paper is correct in that green buildings if implemented at a large scale can act as a catalyst in climate change mitigation and improvement of air quality in Gauteng, South Africa. The recommendation would be an investment from the public sector (government) is quite crucial as the responsibility for the development of infrastructure in the region of Gauteng is primary for them to the society, this can even be explored from a public-private partnership where lessons can be learned from the private sector on how they have managed to achieve building more than 600 green building in just over 13 years in South Africa. Additional elaboration on the advice on methods that could inspire the public sector to invest more in green building development includes but is not limited to, the following. The formation of public-private partnerships would aid in the sharing of resources, expertise, and risk, as well as in finding a balance between sustainability and affordability through careful planning, inventive thinking, and a readiness to adapt and learn.

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