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# Achieving sustainability in South African commercial properties: the impact of innovative technologies on energy consumption



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## Abstract

**Purpose** – This study aims to examine the concept of innovative technologies and identify their impacts on the environmental sustainability of commercial properties in South Africa. This slow adoption is attributed to South Africa's energy building regulation, SANS 204, which does not promote energy-conscious commercial property development. Furthermore, it was observed that buildings waste significant amounts of energy as electrical appliances are left on when they are not in use, which can be prevented using innovative technologies.

**Design/methodology/approach** – The researchers attempted to evaluate the impact of innovative technologies through an overarching constructivist mixed-method paradigm. The research was conducted using a multi-case study approach on green buildings which had innovative technologies installed. The data collection took the form of online, semi-structured interviews, where thematic analysis was used to identify emergent themes from the qualitative data, and descriptive statistics was used to evaluate the quantitative data.

**Findings** – It was found that implementing innovative technologies to reduce the energy consumption of commercial buildings could achieve energy savings of up to 23%. Moreover, a commercial building's carbon footprint can be reduced to 152CO2/m2 and further decreased to 142CO2/m2 through the adoption of a Photovoltaics plant. The study further found that innovative technologies improved employee productivity and promoted green learning and practices.

**Originality/value** – This research demonstrated the positive impact innovative technologies have on energy reduction and the sustainability of commercial properties. Hence, facility managers should engage innovative technologies when planning a commercial development or refurbishment.

**Keywords** Energy, Commercial property, Environmental sustainability, South Africa, Innovative technologies

**Paper type** Research paper



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## 1. Introduction

The main contributor to global warming is $CO_2$ emissions produced through the consumption of fossil fuels. Warming temperatures have resulted in the acceleration of rising sea levels and increased the possibility of extreme weather events (Lindsey, 2019) and higher average temperatures (National Centers for Environmental Information, 2019). This global crisis has sparked the drive toward sustainable development as public pressure has forced governments and companies to accelerate their sustainability drive (Michaelides *et al.*, 2018). However, South Africa is a highly fossil fuel-reliant country, with 92% of the energy being fossil fuel produced and this reliance is not expected to change within the next decade (Philips, 2021). The commercial sector consumes an estimated 18% of fossil fuel-produced electricity, and an estimated 50% of this consumed energy is wasted during non-working hours (Grobler and Masoso, 2010; Baker *et al.*, 2015). This high energy consumption is predominantly due to electrical fixtures and appliances being left on when they are not in use (Gilbride *et al.*, 2017). The lack of green, innovative technologies in the South African commercial property space provides significant opportunities to optimize and manage a building's energy consumption by adopting innovative technologies like intelligent control systems (Elamvazuthi *et al.*, 2014).

Innovative technology can be understood as the introduction of new technologies or ideas that will further the application of scientific ideas (Abou-Zeid and Cheng, 2004). For the purposes of this research, innovation will be defined as technology that is relatively new but, most importantly, not commonly used by commercial buildings in the research territory. This stance was taken from Van de Ven's (1986) definition that an idea, if perceived as new to some people, will be classified as innovative even if it appears to be an imitation to others. This definition follows the slow technological advancement trend facing South Africa (Kotzé, 2019). The lack of knowledge, conflicting building codes, liability concerns and the reluctance of the industry to adopt new types of practices have led to the slow implementation of technological innovation within the sustainability space (Moghayedi *et al.*, 2022). Thus, technologies widely used in developed nations will still be classified as innovative if their presence is lacking in South Africa. Therefore, technologies that are widely used in first world countries, such as smart meters, occupancy sensors, building management systems (BMS) and solar panels will be considered innovative technologies due to their extremely limited implementation in premium-grade commercial buildings (Auerbach, 2014).

This paper aims to understand the impact of innovative technologies on the sustainability of South African commercial properties in the absence of relevant standards and policies related to the effect of the latest technological innovation on energy consumption and building performance of commercial buildings in South Africa. The paper evaluated the current state of energy consumption in the commercial sector, identified implemented innovative technologies and established if these technologies reduced the energy consumption of commercial properties in South Africa.

The novelty of this research rested in evaluating the actual effect of various innovative technologies on energy reduction, $CO_2$ reduction and the sustainability of commercial properties. It aimed to provide more insight into the application of these technologies and identified drivers, challenges and the nexus between technologies and sustainability. The rest of the paper is structured as follows: Section 2 covers a literature review, followed by the research methodology in Section 3. Section 4 presents the findings and discussion, and Section 5 draws conclusions based on the findings. From the conclusion, recommendations were made, and further avenues for research were recommended.

## 2. Literature review

South Africa has a growing middle class that has stimulated investment in the commercial building sector (Boyle *et al.*, 2017). Akinsomi *et al.* (2018) stated that commercial properties account for 22% of all property in South Africa. However, South Africa's slowing economy, excess supply of commercial buildings and increased "work from home" policies have reduced the demand for commercial property space (Moghayedi *et al.*, 2022). This increases the significance of managing a property's operating expenses to maintain profit margins and competitiveness (Kramer and Kramer, 2020).

Eskom, a state-owned monopoly, supplies South Africa with 95% of its electricity, and 92% of this energy production is fossil fuel produced (Kenny, 2015), with their operations generating 1.08 tons of $CO_2$ per gigawatt of electricity (Eskom, 2021). This emphasizes the need to reduce a commercial building's energy consumption by enhancing operational efficiency and switch to more greener energy production, as this reliance on fossil fuels produces exorbitant amounts of pollution. Furthermore, the power utility's ailing infrastructure and inability to meet electrical demands have resulted in load-shedding (Kenny, 2015), highlighting the importance for facility managers to reduce their building's electricity demand and reliance on the municipal grid.

A commercial building consumes significant amounts of energy during its operational phase as building occupant comfort and health has to be maintained over energy conservation (Karadayi and Yüksek, 2017). This leads to building operations being mismanaged and energy wastage accumulation because electrical appliances are not turned off (Gilbride *et al.*, 2017). Furthermore, building occupants are not always aware that their actions have a negative consequence on energy consumption (Von Neida *et al.*, 2001). In the face of the above criticism, proponents of King and Perry (2017) have highlighted the ability of innovative technologies, new energy-saving techniques and energy management systems to optimize and manage a building's energy consumption beyond the human potential.

### *2.1 Sustainability within the commercial property sector*

The World Commission on Environment and Development (1987) stated that sustainability is meeting the needs of today without compromising the needs of future generations. This perspective is critical when viewing sustainability within the context of the commercial property sector, as there are multiple facets used to derive the level of sustainable development. Sustainability is often viewed using a three-pillar model, namely, economic, environmental and social (Mao *et al.*, 2019). The economic pillar refers to managing commercial properties in a financial manner that will provide a continuous income flow in the future (Högberg, 2014). Eklova (2020) argued that the environmental pillar refers to using nondamaging ecological methods to construct and operate a building without exhausting natural resources. The social pillar refers to the distribution and fair access to rights that will improve the quality of life within and surrounding a commercial building (Pieterse, 2011).

South Africa's building standards were re-evaluated in 2011 with the introduction of SANS 204 (2011): Energy efficiency in buildings and SANS 10400-XA (2011) to improve the sustainability of the construction industry. SANS 10400-XA sets out the minimum energy efficiency and sustainability building design requirements, while SANS 204 is a voluntary guideline that marginally improves a building's efficiency beyond SANS 10400-XA. These standards are elementary because they do not create a foundation for sustainable development, and their energy reductions in relation to previous building regulations were minor (Zuo and Zhao, 2014). This relaxed energy limit created an environment that does not incentivize the advancement of innovative sustainable technologies (Kotzé, 2019). Hence, buildings built after the introduction of these standards are still inefficient, and policymakers must aim to improve the policies around building facades, materials used and building techniques before significant investments are made into advanced building technologies. This paradigm is driven by the need for developing nations to update their building regulations to match the developed world's building efficiency ratings (Muringathuparambil *et al.*, 2017). Moreover, Muringathuparambil *et al.* (2017) iterated that a strong regulatory energy efficiency foundation will promote energy-conscious developments and building performance assessment frameworks. Therefore, there is a lack of updated policies and standards in South Africa, which do not develop at the same pace as technological innovations experienced in the developed world.

With the local commercial property sector currently consuming up to 15% of South Africa's energy output due to inefficient operations, commercial properties need to find ways to reduce their consumption, not only in the long term but also in the immediate term (Eskom, 2021). Many modern commercial buildings are built without much consideration for passive design and rely strongly on technology to provide a comfortable indoor climate. Using electricity as the primary energy source to optimize a building's internal climate is inefficient and costly (Sustainable Energy Africa, 2020). While there are many technologies available to this sector, facility managers often find it difficult to decide on the best approach to manage these energy requirements, especially when weighing up the initial outlay cost against the operational cost savings achieved through energy reduction (Eskom, 2021).

To boost the momentum of energy-efficient commercial buildings, the South African government has implemented energy performance certificates (EPCs) that require the monitoring and reporting of energy consumption in large buildings (Sustainable Energy Africa, 2020). From 2021, EPCs are now mandatory for office buildings with a net floor area of 2,000 $m^2$ or over (DMRE, 2020). This will create the foundation for energy benchmarks and efficiency awareness to drive the next generation of resource-conscious developments. Alongside this initiative, an energy tax incentive was implemented in 2013 to encourage private companies to improve their efficiency measures. This incentive scheme has realized savings of 24.7 tWh of electricity and 24.4 equivalent megatons $CO_2$ (Sustainable Energy Africa, 2020). A carbon credit scheme has also been implemented, which allows carbon tax payers to purchase carbon credits and reduce their carbon tax liability (Promethium Carbon, 2019). Therefore, a company may purchase carbon credits to off-set its carbon footprint, and if its building is a positive net carbon zero, then it may sell its carbon credits.

Developers who want to implement sustainable building practices pursue available comprehensive tools, such as the Green Building Council of South Africa (GBCSA)'s Green Star rating system. This rating system provides a higher comprehensive sustainability framework than South Africa's building regulations and rewards companies who achieve these sustainable goals. The GBCSA is the main role player in promoting sustainable building trends in South Africa. They provide the guidelines, tools, and resources to encourage and educate professionals about sustainable development. These goals are accomplished through a formal green star rating system which allows the "greenness" of a building to be measured and compared to similar developments (GBCSA, 2022). This rating system is based on a six-tier grading system with 1 star representing entry-level requirements and six stars are awarded to a strong sustainable building. Moreover, the GBCSA observed reduced operating costs, improved marketability and increased property values due to the reduction in utilities. Windapo and Moghayedi (2020) iterated that corporate image, financial benefits attributed to green buildings, tenants desires and a reduction in a building's carbon footprint will drive the demand for green buildings through using innovative technologies. In contrast to these advantages, the drive toward green buildings has been moderate due to the lack of industry knowledge, conflicting building codes and the unwillingness of the industry to embrace new techniques and practices (Moghayedi *et al.*, 2021).

*2.2 The adoption of innovative technologies in commercial property*

Energy-saving techniques usually employed by developers typically revolve around the design of a building and the materials used. These techniques are effective, but they do not provide the building owner or manager with real-time data collection or control. These energy-saving techniques are considered conventional compared to new energy-saving technologies that rely on automation, artificial intelligence or real-time data collection that will enhance the management of a building (Elmustafa and Zeinab, 2017). These systems will provide buildings with autonomous automation that will collect data in real-time to enhance operational efficiencies (Al-Jaroodi *et al.*, 2019). Cheng (2019) iterated that these systems will also enable facility managers to model and automate scheduled and predictive maintenance tasks. A positive byproduct of these systems was highlighted by Bazzocchi *et al.* (2021), who observed other benefits derived from installing energy-efficient systems, such as reduced waste and water consumption and a decrease in labor costs.

In addition, large amounts of energy data can be collected and used to develop accurate energy models by using automation, artificial intelligence and the Internet of Things, which will create networks to integrate these advances together (Elmustafa and Zeinab, 2017). Using smart meters, smart sensors such as occupancy and $CO_2$ sensors, automated shading systems, integrated automatic vents and self-diagnosis heating, ventilation and air conditioning systems (HVAC), photovoltaic systems, heat capture technologies and other energy-efficient technologies will boost building performance and improve operational cost effectiveness when connected through BMS (Kim *et al.*, 2022). Conversely, the high capital costs to install these technologies have limited their adoption in developing countries (Moghayedi *et al.*, 2022). However, these costs are recouped over a building's lifespan, and economies of scale will reduce their installation costs, and as these types of technologies are improved, their purchase and operational costs will decrease (King and Perry, 2017; Dikel *et al.*, 2018).

South Africa's adoption of technologies has been slow and restricted partly due to minimal sustainability requirements and government reductions in investment and drive toward smart technologies (Kotzé, 2019). Nonetheless, a few municipalities are indirectly promoting technologies through the installation of fiber infrastructure aimed at smart cities. This has driven the adoption of innovative technologies in premium-grade office blocks (Mokoena and Musakwa, 2017). Moreover, the uptake of solar installations is increasing as their installation costs decrease, South Africa's electricity supply worsens, and the cost of electricity increases (Sustainable Energy Africa, 2020). Multiple case studies by the GBCSA (2022) revealed that innovative technologies boosted a building's sustainability rating to achieve a five or six green star rating. However, the actual impact of these technologies on the rating system in terms of energy saving and efficiency has not been quantified.

## 3. Research methodology

A concurrent triangulation mixed method, multiple case study approach was adopted to examine the impact of innovative technologies on the energy consumption of commercial buildings, which used qualitative and quantitative data. To achieve the objectives of the research, three GBCSA green star-rated commercial buildings were selected based on the following parameters.

To begin with, buildings with a five or six green star rating were selected because their energy efficiency levels were optimal. Second, only "As Built" and "Existing Building Performance" green star-rated buildings were considered as they reported on the postconstruction energy consumption. Third, this rating system evaluates nine different categories, and only the energy category was taken into consideration. The resulting energy score was evaluated against the used innovative energy-saving technologies. Finally, the organization that owned the development was analyzed to ensure the cases were diverse in terms of their greening strategies, sustainability initiatives and their corporate image. These five parameters were used to select three case studies.

Qualitative data was collected in the form of semistructured, online interviews with the facility managers. The interviewees were presented with the same set of questions, and they were encouraged to explore any concepts they deemed fit. This approach created an exploratory nature to the interviews. The quantitative data pertaining to energy consumption and building performance of each case study was also collected. Qualitative data was analyzed through thematic analysis and encoded using *NVivo* to establish emergent themes. Quantitative data was treated as complementary data and took the form of a building's energy consumption. This energy consumption was cross compared to the recommended commercial buildings' energy consumption as described by SANS 204. The case study's energy consumptions were consolidated, nominalized and converted into a per square meter rate so that their energy usage patterns could be compared against SANS 204's standard energy allowance. This provided the foundation for the researchers to determine the relationships and trends between the installed innovative technologies and their impact on the sustainability of the case studies.

## 4. Findings and discussion

The analysis of quantitative and qualitative data are presented and discussed below. The findings will first unpack the impact of implementing innovative technologies, followed by the energy savings attributed to green initiatives and solar installations. Finally, the application of innovative technologies and the relationship between innovative technologies and sustainability will be presented. The cases' descriptions and facility managers' profile of each case study is shown in Table 1.

### *4.1 The impact of implementing innovative technologies*

The quantitative data pertaining to the case's energy consumption and types of installed technologies have been summarized in Table 2. The quantitative data was collected at the end of the interviews and comprising the building's energy consumption which was cross

| Case | Description | Facility Manager Profile |
|---|---|---|
| Case 1 | • 6-star "Green Star SA"<br>• Constructed in 2011, total floor area of 18,000 $m^2$<br>• Owner publicly listed property company. | Over 10 years of experience managing South African and UK property |
| Case 2 | • 5-star "Green Star SA"<br>• Constructed in 2014, total floor area of 52,000 $m^2$<br>• Owner publicly listed financial corporation. | Working as a property manager for 7 years |
| Case 3 | • 6-star "Green Star SA"<br>• Constructed in 2007, total floor area of 52,970 $m^2$<br>• Owner publicly listed property company | 7 years of facility management experience and 7–8 years of experience in energy, efficiency and utility management |

**Table 1.**
Cases description and facility manager's profile

compared to SANS 204. Table 2 provides a summary of each case's GBCSA green star rating, energy consumption per meter squared, types of installed innovative technologies and the achieved energy savings of each case.

The quantitative analysis revealed that energy savings of up to 23% can be achieved using innovative technologies in relation to SANS 204's building standard. Case 1 attained the highest savings of 23.59%, followed by Case 2, with an energy saving of 19.34% and Case 3 obtained the lowest energy savings of 16.81%. These findings are aligned with that of King and Perry (2017) and Dikel *et al.* (2018), who observed that innovative technologies will reduce a commercial building's energy consumption.

The number of installed innovative technologies were positively correlated to an increase in energy savings, with Case 1 installing the most innovative technologies. This observation was also proved by King and Perry (2017). The most popular installed innovative technologies were smart meters, occupancy light sensors and BMS systems due to their lower capital costs and widespread application. The other innovative technologies were limited by cost or location, and in the case of Photovoltaics (PV) plants, Case 2 did not have enough roof area for the successful installation of a PV plant.

The age of each case and the technological advancements of energy-saving technologies was positively correlated with more modern buildings. This was evident with Case 2 (Constructed in 2014) and Case 3 (Constructed in 2007), where they both had the same amount of installed innovative technologies, whereas Case 2 was more modern and advanced. Proponents of Dikel *et al.* (2018) also observed that as these technologies improved the operational savings of facilities as technological advancements progress over time, resulting in reduced payback periods. Furthermore, the cases used in this study are buildings constructed with conventional materials and methods without considering fundamental passive design elements. Thus, their installed greening technologies have aided their sustainable nature, preventing the need for demolition or rebuilds to maintain their sustainable levels.

The driving factor behind the installation of innovative technologies influenced the number of installations. Case 1's was environmentally orientated, whereas Case 2 and Case 3 were financially driven, resulting in fewer installed innovative technologies. This resulted from the increased costs of implementing different types of technologies and the longer perceived capital recoupment periods.

As shown in Table 2, there was no correlation between the number of installed innovative technologies and the GBCSA green star rating due to the manner in which it is

| Description | | CASE 1 | CASE 2 | CASE 3 |
|---|---|---|---|---|
| Innovative Technology | Smart meter | ✓ | ✓ | ✓ |
| | Light occupancy sensor | ✓ | ✓ | ✓ |
| | BMS | ✓ | ✓ | ✓ |
| | Automatic shading system | ✓ | × | × |
| | Server room heat capture system | ✓ | × | × |
| | Sea water cooling plant | ✓ | × | × |
| | Solar water heating | ✓ | × | × |
| | PV plant | ✓ | × | ✓ |
| | Integrated $CO_2$ room sensors | × | ✓ | × |
| GBCSA rating | | 6 Stars | 5 Stars | 6 Stars |
| Energy consumption | | 141 kWh/m$^2$ | 149 kWh/m$^2$ | 154 kWh/m$^2$ |
| Energy saving | | 23.59% | 19.34% | 16.81% |

**Table 2.** Summary of each case study implemented technologies and their achieved energy savings

calculated. This rating takes multiple building factors into accounts, such as building material or water consumption, whereas this research only took energy consumption into consideration. Therefore, a building can achieve a five or six green star rating without installing significant amounts of energy-saving technologies.

*4.2 Innovative energy savings technologies attributed to green initiatives vs PV pant installations.* Only Case 1 and Case 3 had PV plant installations because the limited roof space at Case 2 was not adequate for a viable PV plant installation. Therefore, only the latter two cases benefitted from solar energy production. Segmenting the energy savings in each case into solar generation and green initiative savings will indicate the impact that solar generation had on the achieved energy savings. Case 3's solar installation contributed the highest proportion of energy savings (2.79%), followed by Case 1 with 1.66%, as shown in Figure 1.

The savings induced by the PV plant is small because of the limited roof space, with Case 1's solar installation covering 89 $m^2$ compared to Case 3's installation covering 163 $m^2$ in total. The ratio of PV to the floor area of Case 1 (0.5%) is much smaller than Case 3 (13%), but due to Case 1 using more modern PV, Case 1 is able to produce 10 kWh/$m^2$ with a lower PV to floor ratio, which is half of Case 3's production (25k Wh/$m^2$). This supports Dikel *et al.*'s (2018) observation that these technology's efficiencies are incrementally improved as advancements are made within the innovative technology space.

From this analysis, it is observed that the savings induced by the solar installations will not significantly impact the overall savings due to the limited size of the PV systems. Moreover, the actual energy savings achieved through reducing each Case's energy consumption decreased when solar energy was viewed as an alternative energy source. This perspective was adopted from Sustainability Energy Africa (2020), who noted that PV systems will reduce a building's reliance on the electrical grid as it provides a secondary source of power. This finding shows that solar installations are not critical to reduce a building's energy consumption; however, the landlord will immediately receive financial benefits. This follows the state of energy in South African cities (2020) report, which

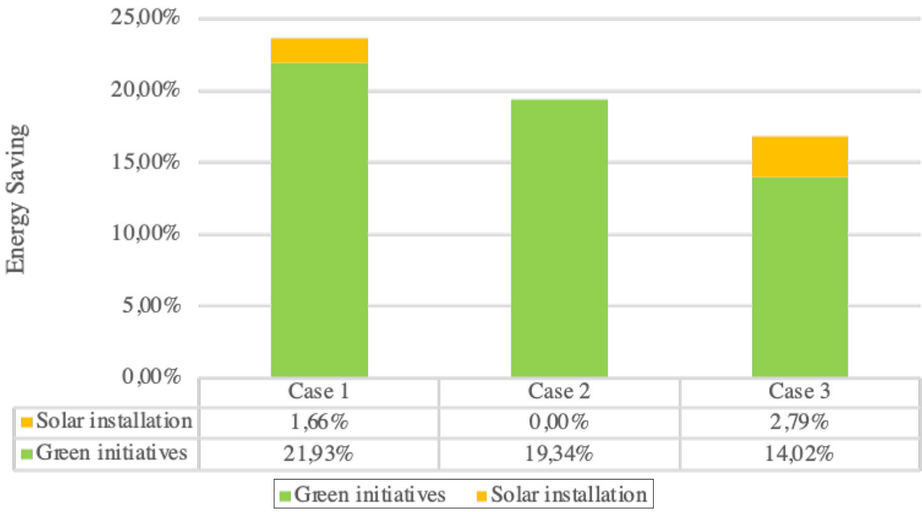


**Figure 1.**
Energy savings attributed to the green initiatives vs solar generation

highlighted the reduced “purchase” cost of solar-generated electricity and the decreased reliance on the municipal grid.

The $CO_2$ analysis revealed that the cases had a lower carbon footprint compared to SANS 204, equivalent 200 kg/CO2/kWh/$m^2$, with Case 1 producing 152 kg/$CO_2$/kWh/$m^2$, Case 2 producing 161 kg/$CO_2$/kWh/$m^2$ and Case 3 generated 166 kg/$CO_2$/kWh/$m^2$. Case 3 had the highest $CO_2$ emission generation; however, taking the solar $CO_2$ off-set into account shifted Case 2 to be the highest $CO_2$/$m^2$ emitter, as summarized in Table 3. This finding proves that the efficiency of the latest innovative technologies is significantly higher than similar technologies produced in prior years, as Case 2 emitted less $CO_2$ than Case 3. However, the ability for a building to install solar panels will generate zero $CO_2$ emissions illustrating that older buildings should invest in solar panels to reduce their carbon footprint alongside of retrofitting their buildings with more efficient technologies. Moreover, due to the rapid advancements in innovative technologies, it may be more beneficial for a facility manager to invest in solar installations. The qualitative analysis discussed later in the paper, found that innovative technologies tend to become outdated rapidly, which creates maintenance challenges for facility managers. Hence, solar panels will provide zero carbon emission benefits without creating maintenance challenges within a few years.

Table 3 shows that the solar installation will further reduce a commercial building’s $CO_2$ operational footprint as fossil fuel energy is substituted for renewable energy. Moreover, the analysis of $CO_2$ equivalent emissions revealed that the PV system is able to reduce Case 1 and Case 3’s facilities operational $CO_2$ emissions by 7% and 6%, respectively, even though the coverage of PV was not optimal.

Comparison of Cases 1 and 3 as two cases with PV systems indicate that the combination of innovative technologies, particularly automated technologies such as occupancy sensors, BMSs, smart meters, automatic shading systems, server room heat capture system and seawater cooling plant with generating solar energy in the site are able to significantly reduce the energy consumption of buildings as well as $CO_2$ emissions. Furthermore, the comparison of Cases 1, 3 (building generating energy) and 2 (no generating energy on-site) proved that the impact of innovative technologies in monitoring and controlling the energy use in buildings is more effective on energy reduction than generating energy on-site. This observation is due to South Africa’s inefficient building designs and lack of building envelope insulations that waste large amounts of energy. Therefore, it can infer that using innovative technologies will significantly improve a building’s efficiency rating beyond South African building energy standards, which aligns with Windapo and Moghayedi (2020).

*4.3 The application of innovative technologies*

Following the thematic analysis using *NVivo*, the subsequent themes emerged from the interviews with the facility managers of three case studies:

(1) energy savings are achieved through innovative technologies;

| Electricity operation $CO_2$ equivalent emission | CASE 1 | CASE 2 | CASE 3 |
|---|---|---|---|
| Total kg/$CO_2$/kwh/$m^2$ | 152 | 161 | 166 |
| Solar kg/$CO_2$/kwh/$m^2$ | –11 | 0 | –10 |
| Municipal kg/$CO_2$/kwh/$m^2$ | 141 | 161 | 156 |
| Reduce kg/$CO_2$/Kwh/$m^2$ | 59 | 39 | 44 |

**Table 3.** Electricity operational $CO_2$ equivalent emissions

(2) followed by an analysis of the capital cost to install innovative technologies; and
(3) their operational impact. Finally, the drivers propelling the installation of innovative technologies will be examined.

*4.3.1 Energy savings achieved by innovative technologies.* A reduction in energy consumption was apparent between all the case studies. All participants agreed that PV plants reduced their energy consumption, with Case 3 directing PV-produced power back into the electrical grid during off-peak hours. This observation indicates that facility managers view PV plants to decrease their grid energy consumption instead of viewing PV-generated energy as an alternative energy source.

Lighting constitutes about 22% of consumed electricity which makes it an important electrical fitting to focus on. This led one case to replace their outdated lighting system with modern LED's which consume between 2 W and 3 W per fitting. These types of fitting replacements contribute to significant energy savings when they are implemented over a large scale, such as a commercial building, contributing to a five to six years payback period and even a payback period of as little as one year can be achieved in specific cases.

However, energy savings are not always achieved due to individuals wanting a comfortable working environment. An example of this is in the morning when the building has lost its heat overnights due to poor insulation, a common problem in South Africa, and because the HVAC system turns off at the end of the day due to the energy crisis in South Africa. When occupants start arriving for work, the occupancy sensors pick them up, and the HVAC system turns on. However, this process takes time before the office is heated to a suitable temperature. Building occupants do not enjoy this as they want the building's temperature to be suitable upon their arrival. This leads tenants to override the occupancy sensors preventing the energy-saving benefits from being realized. Consequently, the landlord can work with the tenant to alleviate these problems through contractual agreements or incentive policies. If the tenant sees the landlord is constantly taking steps to improve the energy efficiency of the building, then they will be more accommodating to these inconveniences. In the end, the tenant will benefit from the reduced utility bill.

*4.3.2 Capital cost to install innovative technologies.* The capital cost associated with each innovative technology was the main financial driver observed in Cases 2 and 3. However, Case 1 was an exception, with the core values of the shareholders, investors and employees driving the implementation of energy-saving techniques and technologies. Typically, investors and shareholders want to see their returns as quickly as possible, making capital cost the main driving factor. At the same time, installing innovative technologies will also depend on whether you are in the design and build phase, construction phase or retrofit phase. With retrofits, the cost of installation is high, but companies are more aware of the reduction in utility bills as they can effectively analyze their expected energy savings.

Similarly, the payback period of the technology is used to determine the feasibility of the installation. Therefore, where the cost to install a technology was prohibitive in relation to the expected savings, the installation was foregone. Additionally, one of the main problems expressed by the facility managers was the rapid rate at which these types of technologies became obsolete, and within five years, they were unable to find parts for some of their systems. To overcome this challenge, maintenance and replacement schedules must be drawn up to reduce the chance of unforeseen costs and indicate expected technology life expectancies. This can create tension within the company as discussions become heated around the amount of money being spent on these types of technologies and whether they are financially viable in the long run. Despite this criticism, it was noted that the current advancements within the energy-saving technology landscape have considerably shortened the payback periods. With the payback period of lighting being as little as one year. While the payback period for solar PV plants ranges between five and seven years maximum, compared to seven and eight years for older installations.

*4.3.3 Operating costs derived from innovative technologies.* The facility manager (FMs) indicated that operating costs related to building maintenance and utilities were reduced. Moreover, the FMs expressed the compounding effect achieved by multiple technologies working together; for instance, the light occupancy sensors will not only control the light fixtures but also communicate to the HVAC system about the occupancy level within a room. Additionally, innovative technologies will help a building scale it is thermal comfort operations without incurring exponential costs:

> [. . .] with our employees almost doubled in numbers, but I do believe we are well within that framework and we've actually dropped our energy consumption the first five years by 1% a year [. . .].

It can also be said that the reduced operating costs will also dampen the financial effects of a slowing market in relation to a company's profits. From an energy perspective, tenants are more cost-sensitive because energy efficiency awareness created from such systems educates the tenant on the potential savings of practicing energy-efficient strategies and policies.

*4.3.4 Innovative technology drivers.* The main driver behind the implementation of said technologies is the financial gains and savings attributed to them. Furthermore, these systems also help companies reach their carbon emission reduction targets helping with their green image. However, providing occupants and employees with a comfortable working environment is the main priority. Therefore, if employee productivity comes at the cost of being less energy efficient, companies will prioritize employee productivity.

A secondary driver of the installation of innovative technologies is the benefiting party. This follows the trend that the party spending the capital wants to see a return. In the case where a tenant pays for the electricity used for lighting, the landlord would not spend additional capital to improve the lighting's energy efficiency because they will not obtain any financial benefit. However, if a PV plant is installed, electricity can be sold to the tenant and the capital costs will be recuperated. Additionally, the building will also be perceived as green, thereby increasing its marketability:

> It's efficiency first and then you add your additional generation capacity, whereas property owners do tend to do it the other way round. And the big motivation behind that is if I'm going to spend the capital, I want to return on a capital.

### *4.4 The nexus between innovative technologies and sustainability*

All the facility managers were familiar with the three pillars of the sustainability model. It was interesting to note, however, that none of the participants had a defined definition, but they possess a similar understanding of the concept. Furthermore, no one specific pillar was referred to as being the focus of the project, rather the facility managers dealt with all the elements of sustainability. This sustainability concept will be broken down below using the three pillars of the sustainability model.

*4.4.1 Economic sustainability.* It was found that the installation of innovative technologies increased the value of the buildings and improved their financial operations due to lower operating costs:

> The moment I put up a PV plant, I have the green credentials, and I have the direct financial returns.

It was further observed that the cases were able to reduce their energy demand from the electrical grid and even reduce the effects of an energy crisis, such as load shedding and incrementing energy tariff increases. This operational cost reduction creates additional disposable income from the finance that would have been spent if no energy savings were achieved, which follows Högberg's (2014) observations of improved liquidity and operations that will provide a continuous income stream in the future.

*4.4.2 Environmental sustainability.* The primary focus of the installed technologies was to reduce the building's carbon footprint. This commitment to environmental sustainability does not end with the completion of a single project but has the benefit of influencing future developments. Investors and developers are always seeking to improve their green building designs to obtain a higher green star rating, thus, resulting in continuous improvements in energy management technologies and techniques. This drive has propelled the companies to pursue environmental, social and governance and carbon footprint reporting, which allows the facility managers to track and monitor their operations.

*4.4.3 Social sustainability.* The cases may practice social sustainability in a variety of ways, and it is difficult to define it in the context of innovative technologies. All the facility managers claimed that these green technologies improved the building's working environment, which increased employee productivity. Furthermore, an indirect social benefit stemmed from innovation. This concept referred to the case studies implementing similar initiatives to other successfully implemented green technologies. By the same token, the company's green initiatives created environmental awareness amongst the employees who would take these habits home, increasing the reach and practices of sustainable living beyond the company space:

> A lot of staff went home and tried to see how they could do things differently in their own homes. I still get a lot of calls asking me how they should wire their home or what can they do to be more environmentally friendly.

## 5. Conclusion

The study recognized different types of implemented innovative technologies and compared the level of energy consumption of each building to the recommended energy consumption for commercial properties as indicated by South African building standards. It was evident that the level of sustainability was impacted by the number of installed innovative technologies, and the familiarity and knowledge of facility managers with these advanced technologies drove their implementation.

The results indicated the reduction in energy use reduced both the primary electricity usage and the $CO_2$ equivalent emissions. This is of high importance when the country faces an energy crisis and the primary electricity supply in South Africa is 90% fossil fuel produced. Segmenting the energy savings achieved by each case showed that solar installations only contributed marginally toward energy savings in the absence of passive buildings; however, their impact on operational $CO_2$ emissions was significant. This distinction between the marginal efficiency gains and significant $CO_2$ reductions indicates that solar panels will only generate green power without improving the efficiency level of a building's operations. Therefore, facility managers should aim to install solar installations, if possible, to help off-set their building's operational carbon footprint. However, should the facility managers prefer improved energy efficiencies, then they must invest in other technologies such as BMSs, occupancy sensors and smart meters.

The findings revealed that the installation of innovative technologies was driven by the financial sustainability pillar, but their application also had a positive effect on the other two pillars of sustainability. The environment pillar benefited from the reduced utility consumption as less resources are consumed to maintain a comfortable working environment. Therefore, a positive relationship exists between the number of innovative technologies adopted and the amount of energy reduced (operating costs). The findings further revealed that innovative technologies not only had a positive impact on economic and environmental sustainability by reducing their energy consumption but also strengthened social sustainability by enhancing the working environment and the implementation of sustainable habits at home. Thus, the installation of innovative technologies to decrease utility consumption and lower the carbon footprint improved employee behavior and lifestyle choices.

The energy savings achieved by each case study emphasizes the positive correlation between the number of installed innovative technologies and their energy reductions in relation to SANS 204. By the same token, this energy consumption reduction improved the carbon footprint of the buildings, and where solar panels were installed, significant $CO_2$ emission reductions were experienced. Most notable throughout the study, the installation of innovative technologies improved the energy efficiency of the buildings beyond SANS 204's standards, highlighting that developers must aim to integrate these technologies into their buildings to meet or exceed SANS 204's standards. Furthermore, it was also observed that improved efficiency of innovative technologies was experienced as technological advancements were made. Thus, commercial property developers must invest in innovative technologies to reduce their energy consumption, utility costs, carbon footprint and operating costs. Moreover, these technologies will also aid a building to be sustainable, reducing the need to demolish or retrofit to be sustainable.

Although the adoption of innovative technologies to improve the energy consumption and building performance of commercial properties in South Africa has increased in past years, the South African built environment sector still lacks the latest building standards and policies, particularly in passive buildings, energy, environmental sustainability and technological innovation in operating buildings. The results of the study highlighted that achieving high energy efficiency buildings such as net-zero cannot be prosperous until all required building and energy standards and policies are developed and implemented in South Africa.

The findings of this study, with respect to each case's energy savings, were collected in terms of the whole building's energy consumption. Moreover, the operating and capital costs of the installed innovative technologies were not obtained due to nondisclosure of intellectual property. Therefore, further research with respect to innovative technology's capital outlay, energy consumption and maintenance costs will generate a more comprehensive financial forecast model. Additionally, only three cases were investigated within South Africa. To improve the accuracy of the findings, it is recommended that a larger sample size be used in a future study.

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## Further reading

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