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Final Report

State of Digital Transformation with specific focus on the energy efficiency potential on energy demand in the Buildings Sector

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Glossary of terms

AI	Artificial Intelligence
BI	Business Intelligence
BMS	Building Management System
CEEP	Centre for Energy and Electric Power
CO_2	Carbon dioxide (emission)
DENEFF	German Industry Initiative for Energy Efficiency
DMRE	Department of Mineral Resources and Energy
DSM	Demand Side Management
EEDSM	Energy Efficient Demand Side Management
EPC	Energy Performance Certification
ESKOM	South African Public Electricity Generation and Supply Utility
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communication Technologies
KPI	Key Performance Indicators
LED	Light Emitting Diode
M & E	Measurement and Evaluation
M & V	Measurement and Verification
POPIA	Protection of Personal Information Act
QDCT	Qualitative Data Collection Techniques
SANEDI	South African National Energy Development Institute
SCADA	Supervisory Control and Data Acquisition
TOU	Time of Use
TUT	Tshwane University of Technology

Editorial

The ever-increasing economic human activities nowadays have rapidly accelerated climate change and its disruptive effects. Numerous unprecedented risks and hardships are imposed on people and all forms of life on our planet.

A net-zero approach requires that all man-made greenhouse gas emissions must be removed from the atmosphere, allowing to be re-absorbed from the air, by oceans and forestry, maintaining the previously established balances in the nature.

The energy generating industries are the principal source of greenhouse gas emissions today. Transforming these industries together with the transportation sector is the key action in the avoidance of the worst effects of climate change.

This is achievable by nothing less than a wide-ranging makeover of the way the energy is generated, transported, and utilized.

South Africa's electricity generating economy is based predominantly on coal technologies and the country is a relatively large emitter of greenhouse gases.

As a signatory to the Paris Accord, South Africa has committed to reaching net-zero carbon emissions by 2050. Looking at the present status of South African energy generation and consumption patterns, this will require considerable efforts and programmes affecting the entire economy and society.

South African buildings, both commercial and residential, present a significant part of the connected grid load. Normalizing the electricity supply of the country in a sustainable and environmentally friendly manner requires major changes and digitalized intelligent load optimisation, monitoring, forecasting and controlling.

The acceptance and commercializing by South Africa of the present buildings digitalisation trends in use around the world, offer attractive opportunities to resolve the electricity supply challenges of the country.

Digitalisation as a broad idiom, is the digital transformation by automating and optimizing business processes using modern digital and connected technologies.

In the South African context, there would be major benefits of the digital transformation of public and private organizations and businesses housed in the commercial and residential buildings. The rapid advancement in building digitalisation could lead to significant improvement of the current strained state of the energy generating and supply industry. In addition, digitalisation would be the catalyst for initiating and resolving a variety of socio-economic development deliveries, while creating new "green" jobs, improving business process, and providing better working and living conditions for the South Africans.

After the COVID-19 pandemic, now the war in Ukraine is going on. These unplanned disrupting events alone are changing the world's economies and already are affecting people's lives and will, with no doubt, touch the building digitalisation process. On the positive note, digitalisation could become more attractive since the energy savings and the other benefits would have more value due to the escalated energy prices internationally.

I wish you an interesting read.

Greetings,

Prof OD Dintchev
Project Team Leader, Tshwane University of Technology

Executive Summary

Globally, buildings consume 40% of the world's energy, while 80% of their total lifecycle costs constitutes the building operating costs [12]. This makes buildings a target group for new digital technologies, automation, energy efficiency and conservation, whereas providing better and healthy working and living environments.

In the South African context, digitalisation of buildings **contributes towards maintaining a stable electricity supply** in the country. Also, this could be an essential contribution towards the Government's goal to **reduce greenhouse gas emissions to net-zero** by 2050 as well as the **implementation of the Digitalisation Strategy**.

This study was conducted by the Tshwane University of Technology (TUT) as commissioned by GIZ, (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) in Pretoria in collaboration with the South African National Energy Development Institute (SANEDI). The study aimed to conduct a review on the state of digitalisation in the buildings sector. The buildings sector in this regard is limited to commercial and office (public and private) buildings.

The research methodology was based on the evaluation of digitalisation, also known as digital transformation, as a process of automating and optimizing business models with the help of technology to achieve energy efficient operations.

The evaluation was executed with the understanding that the state of buildings digitalisation maturity in South Africa is governed by the mitigation of the impacts of the insufficient capacity of the country's electricity generation capacity on the business and living conditions in the buildings.

Several South African buildings were evaluated considering the building Clusters Classification of Building Occupancy and Building Description in accordance with the South African Standard SANS 10400-XA:2021 [3].

The buildings were evaluated while considering the following technologies as the important levers in optimizing the buildings assets: Lighting, Heating, Air Conditioning, Ventilation, Security and Access Control systems along with efficient, automatic monitoring and control.

A review of the building digitalisation stages in developed countries namely the USA, Germany, Sweden, and the UK was performed.

Questionaries based on the governing factors of building digitalisation were developed and used as a base to evaluate the main buildings clusters in South Africa. These were complimented by site visits.

The digitalisation maturities of the local and overseas buildings were compared, although the different countries have different priorities in implementing digitalization.

The focus of digitalisation for the South African buildings is to ensure normal and healthy working conditions in buildings in an environment where scheduled and non-scheduled electrical outages are a common occurrence.

The study identified the leading building in all clusters and concluded that the digitalisation stage of the local buildings with high digital maturity ranks/scores close to the (average) maturity levels of the other countries reviewed. However, the number of the local buildings with noticeable digital maturity is much less than their foreign counterparts. The reasons being: political, socio-economical, technological, ecological, and cultural amongst the others.

Yet, the study pointed out that the digitalisation of the South African buildings could be very beneficial in many respects to the country and the South Africans.

The main benefits in this regard are:

- Contribution in increasing the electricity generating capacity by introducing sustainable electricity generating sources
- Reducing both the base and peak loads of the country by energy efficiency and alternative energy implementations
- Reducing the carbon footprint
- Mitigating the secondary effects of the COVID-19 pandemic on the economy by creating new green jobs and addressing gender equity issues
- Health benefits by creating healthy and enhanced working environments, tailor-made to avoid and prevent the restrictions due to the present and future pandemic(s).

In general: Buildings of today and tomorrow need to be digitalized to provide better flexibility, improved healthy working conditions, as well as increased adaptivity and resilience for ever-changing local and global disruptive events.

State of Digital Transformation with specific focus on the energy efficiency potential on energy demand in the Buildings Sector

1. Background

With buildings contributing around 40% of global energy-related emissions, the #BuildingToCOP26 Coalition was instrumental in bringing together national, regional, and city-level leaders, alongside the private sector, to showcase the building sector's critical role in achieving zero emissions, a resilient future, and the deep collaboration needed to accelerate climate action [1].

The digitalized, net-zero-buildings use energy extremely efficient and are supplied by renewable energies. In the South African context, digitalisation of buildings offers a major potential for the maintenance of a stable electricity supply in the country. This could be an essential contribution towards the Government's goal to reduce greenhouse gas emissions to net-zero by 2050.

To initiate the series of studies, the South African – German Energy Partnership in collaboration with South African National Energy Development Institute (SANEDI) appointed the Tshwane University of Technology (TUT) as a service provider to conduct a study on the maturity of digitalisation of the buildings sector. The buildings sector in this regard includes commercial and office (public and private) buildings.

Ultimately, SANEDI will use the information generated by the study to inform and advise the Department of Mineral Resources and Energy (DMRE) in its policy-making decisions.

The scope of the study was to include:

1.1 Global analysis

Limited to four countries that are advanced in applying digital technologies for energy efficiency purposes in the buildings sector. Germany, the USA, the UK and Sweden were selected for this analysis. This was to provide:

a. an overview of the **key market forces driving change** in the global buildings sector. These should include but are not limited to the areas of sustainability, decarbonisation, new business models and digitalisation.
b. an overview of the **digital trends** and outline the **impact** of digital transformation in the global buildings sector regarding energy efficiency.
c. an overview of the **key technologies** behind the digital trends.
d. an overview of the **state of digital adoption/ digital maturity** of the global buildings sector.
e. an overview of the **top digital solution providers** in the digital buildings space with a South African presence, including their value proposition, key activities, and target customer segments.

1.2 South African analysis

Limited to:

a. **As-Is Situation** to provide an overview of:
    i. the digital adoption/ digital maturity in the buildings sector in South Africa from a private and public sector regulatory framework perspective.
    ii. the digital trends in the South African buildings sector.
    iii. review the existing regulatory framework/ national strategic documents and assess the potential impact of COVID-19 on the developments.
b. **To-Be potential**: Compile the key opportunities of digitalisation for the buildings sector, focussing on energy efficiency/savings potential and additional job opportunities.

1.3 Disclaimer

The main purpose of this study is to evaluate the digitalisation maturity of South African buildings with an emphasis on energy efficiency and ability of the buildings to minimize the operating costs, while improving the productivity and working / living conditions of the occupants. Since all these would lead to the improved business performance of the building, all the contributing factors are subject to commercial confidentiality thus influencing the competitive edge of the buildings as commercial entities. For this reason, the study is quantifying and evaluating the buildings as clusters /groups (without using their commercial names) to observe the privacy and confidentiality of the information.

2. Introduction

Globally, buildings consume 40% of the world's energy, while 80% of their total lifecycle costs constitutes the building operating costs [2]. A digitalised building (workplace) exists at the intersection of: People, Organizations and Digital Tools, as shown in Error! Reference source not found..

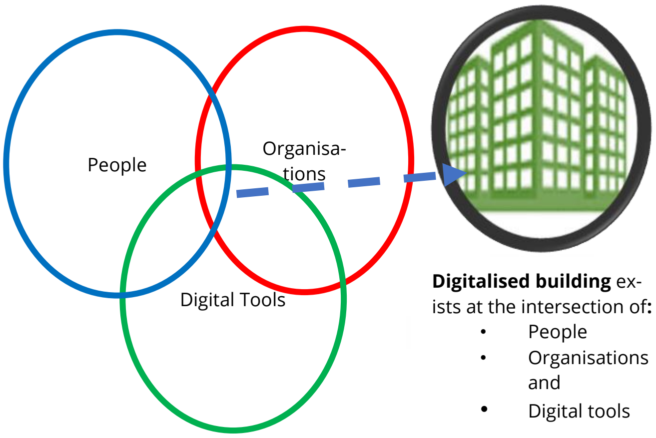


Figure 1. Digitalized building

The primary focus of building's digital transformation is on enabling employees and management to ***accomplish relevant business targets***. As illustrated in Error! Reference source not found., digitalising a building will result in benefits such as improved business process, increased energy efficiency and optimized operating costs.

The entire business operating model is a complex and dynamic matter that can greatly be improved via digital transformation. The focus of this study is on the ***energy efficiency potential*** as arising from global digitalisation trends. This feature of the investigated buildings is very significant to the present South African business environment. In this perspective, the significant building assessing variables / targets in improving buildings operational efficiency could be summarized as:

- Energy optimization
- Lighting
- HVAC
- Security control systems
- Efficient, automatic monitoring
- Data analytics to optimize all the above
- Integrated system of sensors, inter-connected and communicating on multiple platforms.

In contrast to the buildings digitalisation in other countries, the main challenge for the South African digital transformation in the buildings sector is the ***availability of reliable electricity supply***, a result of the shortage of generation capacity in the country. In other words, improving buildings operational efficiency continues to drive the implementation of digital technologies in building operations.

Therefore, in the South African context, one of the main KPIs for buildings digitalisation will be the ability to **mitigate the effects of interruptions** to the core business processes during planned and non-planned interruption of the electricity supply. Digitalisation offers valuable options to predict and overcome the above challenges through **Artificial Intelligence (AI) and Business Intelligence (BI) solutions**.

3. Digitalisation in buildings operation – global overview

There is a consensus among facilities' managers, owners and other facilities' stakeholders that digitalisation is the next step towards a greater operational efficiency in business operations as it brings about process automation, optimizes operations, and enhances functionality, comfort (indoor climate), safety, and efficiency of buildings and other infrastructure.
The primary focus of building's digital transformation is on enabling employees and management in accomplishment of relevant business targets.

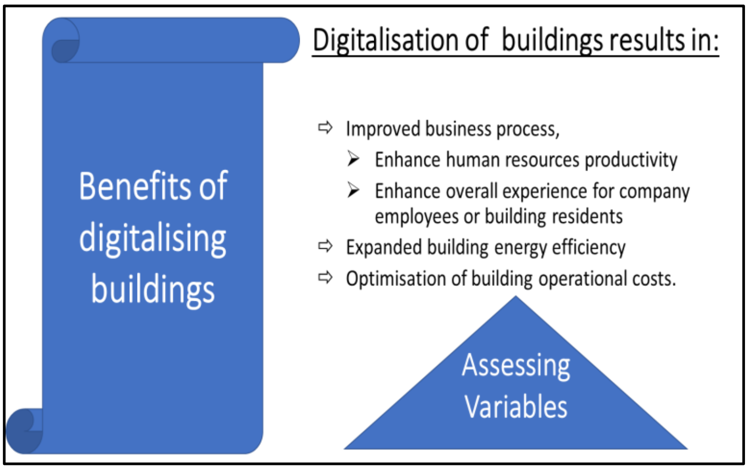


Figure 2. Benefits of digitalising buildings

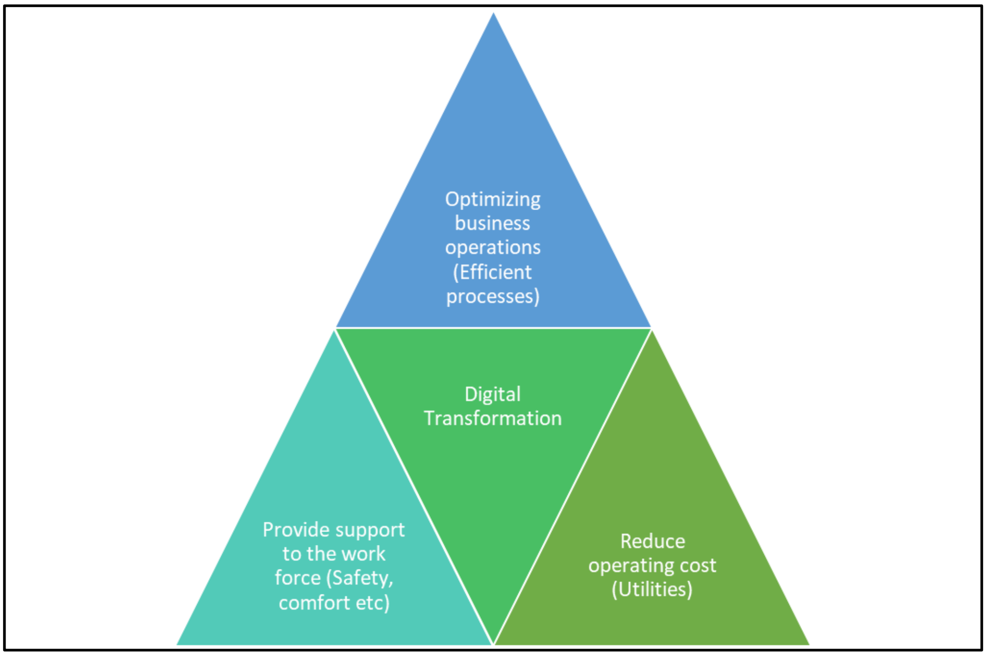


Figure 3. Digital transformation effects on business operations

Due to the complex and dynamic nature of business in the information age, digital transformation should consider the particularity of the business so to maximize productivity, e.g., detecting the replicable processes to then build a standard workflow and remove the unnecessary processes or reshape the workplace to be more attractive and flexible for end-users. This includes the use of **sensors** to proactively detect and report inefficiencies and malfunctions, speeding up **improvements of processes** within the facility and communicating this via multiple digital platforms. This is shown in Error! Reference source not found. where the impact of digital transformation in the various areas of businesses is illustrated. Synergising the application of digital technology into the core aspect of a business would result in **increased productivity, increased business revenue** in the medium and long term and transforming the workplace into a **healthy and safe environment** where it is pleasant to work.

Major contributors to operating cost in businesses – other than human resources – are the utility costs including energy, water, waste management and connectivity. An increase in efficiency in any of these core business needs would provide a competitive advantage for the business and ensure sustainable growth. As a core element of energy systems, energy efficiency is fundamental in addressing operational challenges for the energy needs of businesses. Recent digital innovations are offering new ways of looking at the existing energy efficiency challenges and finding creative strategies to address these challenges, while providing a completely new opportunity to advance energy efficiency to the next level. For maximum effectiveness, these strategies are to take into consideration the entire energy sector from generation to consumption and beyond. The crucial elements of digital integration in the energy sector can be stated as follows [4]:

- Value proposition
  - Increased system efficiency (energy efficiency and energy conservation)
  - removal and/ or recycling hazardous waste from the business process
  - Innovative business models
  - Effective policy-making and its implementation
- Benefits
  - Data accessibility and usability – automated and transparent reporting for M & E and M & V purposes
  - Automation and connectivity
  - Empowered consumers and other stakeholders
- Resources
  - Digital technologies and platforms
  - Relevant expertise of different segments
  - Clear leadership and communication

A global exploration into the advancement/penetration of digital technologies in building energy management showed different focus in implementation [2]. While in the **US market**, the emphasis is placed in transforming buildings and facilities into flexible loads for grid operations [5], in the **German market** the focus is primarily on energy efficiency and grid integration remains second [6]. This is naturally shaped by business needs, policies, and current regulatory frameworks in the respective markets / countries. In turn, preferred strategies are adopted based on what makes the most business sense. As a result, strategies developed or adopted vary country by country. These strategies include:

- Energy efficiency: reduce consumption with same or improve level of building function. It has the greater potential of minimising utilisation cost.
- Load shed: reduce consumption for a short period ensuring that the building functions are not negatively affected. Usually done during peak demand when energy cost is high.
- Load shift: manage timing of energy use from high demand periods to low demand periods. Impact on overall energy used is low but potentially has a greater cost to benefits ratio.
- Modulate: quick response to grid signal to balance active or reactive supply and demand to prevent system instability and possible blackouts.
- Generate and store energy: on-site generation and storage (electrical or thermal energy) for on-site consumption primarily and grid supply (electrical only) in response to request from the grid operator.

Passive technologies such as building envelope, windows and daylighting considerably increase the efficacy of these strategies made possible with digitalisation [5]. In fact, as buildings are used as flexible grid resources, they could be considered as thermal and electrical storage unit from the grid operator perspective.

3.1 Market forces driving digitalisation in the buildings sector

Challenges such as **cost, availability and reliability of electrical energy while ensuring a sustainable and environmentally conscious growth** in various sectors of the economy are driving the introduction of innovative solutions as a holistic solution taking into consideration multiple and interdependent constraints. Digitalisation has been shown to present a solution to these challenges in ways that could not be achieved otherwise. This drives the digitalisation process in buildings, which is a considerable contributor to the total energy consumed globally. In addition, the advances in information and communication technologies easing the transformation and generating large volumes of data are stimulating the building energy efficiency enhancements, while creating immense opportunities for reducing the operational costs and increased productivity.

The increased stress on the electrical infrastructure due to the rising share of variable renewable generation affects the reliability and energy costs to end-users. Coupled with rising power generation cost and transmission capacity constraints, alleviating the stress on the electrical infrastructure would require a more flexible control of supply and demand in a grid that is more and more decentralised. This involves the control of resources connected to the grid including buildings, electric vehicles, and any other controllable and shiftable loads with the aim to ensure the optimal grid operation, minimum cost and reduced reliance on non-renewable energy sources.

Digitalisation provides the opportunity to tap into end-use energy efficiency through optimisation, control, and data analytics, effectively moving from a single end-use efficiency to a systems wide efficiency sought out by grid operators to alleviate the pressure on the electrical infrastructure. It is reported that digitalisation has the potential to reduce energy use in buildings by 10% globally by 2040 if integrated into the building value chain and lifecycle [7].

The buildings sector presents the largest opportunity for grid interaction and energy efficiency. In the US market, for example, this sector is responsible for more than 40% of energy consumption (all building types combined) more than transportation and industry. It is estimated that 75% of all electricity produced in the US is consumed in buildings [5]. However, the buildings electricity consumption is largely decentralised comprising of multiple small to medium energy users such as residential dwellings, small and large business buildings spread on a very large geographical area, which presents difficulties in achieving the intended goals for grid interaction. Digitalisation is seen as the means to offer the necessary insight, through appropriate analytics, to manage and control loads for a coordinated demand response and system energy efficiency on a large scale.

The ultimate goal is to turn buildings (of all sizes) into flexible grid resources – match consumption to actual energy needs via automatic and intelligent controls, while keeping them useable for the occupants e.g., prioritize occupant preference and comfort [5]. This would, for example, automatically adjust temperature and airflow based on occupancy, control illumination via a combined lighting and automatic blind control to name a few. On average, 11% to 22% of energy savings are possible in the second year after implementation of a building digital energy management system in commercial buildings [3].

As the COVID-19 pandemic changed fundamentally the way of working of millions of people globally, most of the buildings especially offices have drastically reduced their occupancy levels leaving very large areas of office space unused. With more people having left the offices to work from home in the last 2 years due to the Covid-19 imposed social distancing measures, digitalisation could be leveraged to elevate the building operation. Building systems could be optimised based on the actual occupancy where building services in the offices and areas frequently used by the personnel present in the building on a specific day would be prioritised. The occupancy information could be collected from the access control and security systems and linked to the building energy management system.

System efficiency is to be achieved by linking multiple buildings virtually as flexible resources for the grid. This will turn passive consumers – building operators and owners - into active consumers. If incentives are provided, load could be shaded on a per building basis when not critically needed e.g., reduce HVAC consumption in portions of a building when not occupied, or dimming the lights while opening automatic blinds in another portion of the building with sufficient sunlight. This, however, is not limited to controllable and shiftable load but also to generation within buildings where embedded generation, preferably renewable, is present and could be made available to the grid operator.

An estimated 20% in operating cost savings can be achieved by making a building grid-interactive and efficient through digital technologies [2].

In the **German context**, the digitalisation market is seen as the crucial path towards energy efficiency for a neutral carbon objective. Most German utilities are of the opinion that decentralised energy generation, efficient use of power and grid flexibility are the most important fields in which digitalisation should apply [8]. This belief is shared by more than 170 energy efficiency service providers who are members of DENEFF (German Industry Initiative for Energy Efficiency), a strong advocacy voice for energy efficiency [6].

These technologies would be able to pool together small-scale generation capacity and enable peer-to-peer energy trading giving a more active role of consumers in the energy market. This is critical in the future of the German's energy market with the commitment to shift from large, centralised energy generation via fossil fuel toward a mixed mode of generation including distributed renewable generation. This transformation has already seen the share of renewable energy increase to about 50% of generated electricity in Germany, from wind and solar mostly.

Digitalisation is developing fast through the active support of DENEFF, its members, and various partners in the German's wider industrial sector [6]. The primary objective is the optimisation of the energy systems with better, cheaper, faster, convenient, and more reliable energy solutions. By making use of digital technologies, intelligent and adaptive controls, **that could develop energy saving strategies** in ways we might not understand thanks to optimisation via artificial intelligence and machine learning. This affects energy efficiency but also demand side management for the optimisation of the electric system, (production, storage, transmission etc.). It is estimated that digitalisation in the energy sector would save as much as EUR 7.7 billion in the German energy sector [8].

3.2 Digital trends and key technologies

The number of connected devices with automated control – including appliances, devices, smart meters, sensors, BMSs– is increasing exponentially and by 2021 has exceeded the number of people [9]. It is estimated that each household, on average, has 50 connected devices [10]. As connected devices related to automation and end-use energy efficiency reach the market, they rapidly expand at a yearly exponential rate. By 2030, it is estimated that connected devices will reach 50 billion worldwide [9]. In addition, the control flexibility offered by these smart appliances – valuable in terms of active monitoring and demand response from grid operations – these devices are generally more efficient than the appliances they would replace. Utilities and end-users both benefit from the uptake of smart devices as new business models around utilisation of smart and connected devices are developed.

An indicator of the rapid uptake of digital technologies in the energy sector is the number of start-ups focused on digital energy businesses reaching 64% of global energy start-up globally in 2020 despite the COVID-19 pandemic [2].

Business models are shifting focus from utilities and supply products – a centralised approach to energy management – **to user-centred energy services** with a potential to generate up to USD 10 billion across France, Germany, Italy, the Netherlands, Spain, and the United Kingdom [2]. The focus on these new business models is on **software development, optimisation and artificial intelligence applications** for energy efficiency and grid flexibility – business-to-business, business-to-customer, customer-to-customer and customer-to-utility energy trading and demand response. Major traditional players in the energy sector have partnered with upcoming start-ups to take advantage of the innovative technologies developed for an efficient and flexible digital grid.

Based on several case studies, building energy management systems (BMS) based on digital technologies have shown to reduce energy consumption significantly [2]. The impact is context dependant and can be subdivided in two broad technological categories:

- **Device level technologies**
  - Smart LED lighting – 40 to 50% of savings
  - Smart windows & HVAC consumption – 20 to 25% of savings
  - Smart electric motors – 10 to 20% of savings
  - Smart water heating – 10% to 15% of savings
  - Smart thermostats & HVAC consumption – 5 to 10% of savings
- **System level technologies**
  - Fully integrated with efficient smart appliances – 30 to 40% of savings
  - Monitoring and managing automation – 20 to 30% of savings
  - Smart zoning thermostats – 10 to 20% of savings
  - Behaviour changes from monitoring feedback – 5% of savings
  - Fault detection and diagnosis – 5% of savings

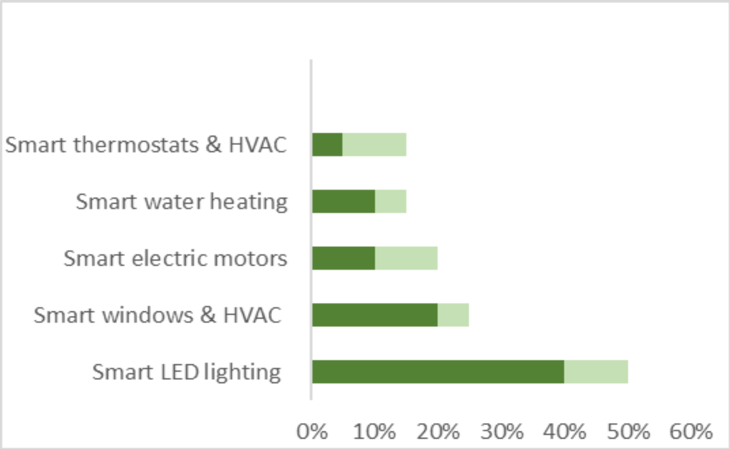


Figure 5. Energy efficiency with digital devices - Device level technologies [2]

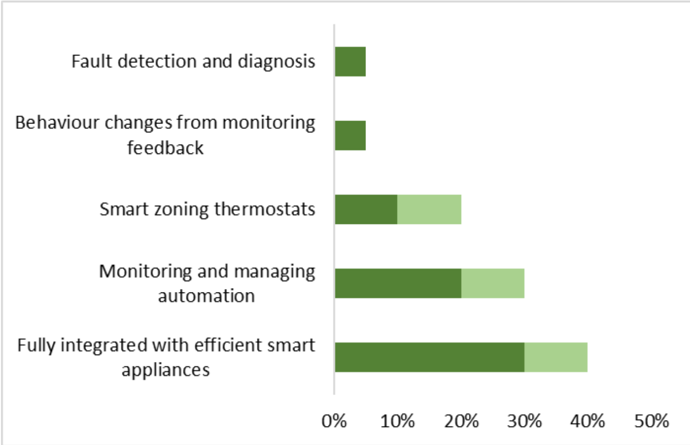


Figure 4. Energy efficiency with digital devices - System level technologies [2]

Performance on individual technologies/interventions could be compounded if implemented concurrently provided that appropriate strategies are employed. However, the large adoption of connected devices in buildings adds a non-negligible energy demand when compared to non-connected devices. To maintain connectivity, these devices will consume an additional 0.2W to 3W when active or in standby mode as compared to non-connected devices [2]. This could considerably reduce the energy performance of certain connected appliances that are expected to be idle for extended periods. However, with economies of scales and continuous improvements, the **energy intensity of connected devices is expected to be halved by 2040 to account for 275 TWh of energy consumed globally per annum compared to an estimated saving of 4 650 TWh** yearly due to efficiency and optimised controls made possible by connected devices [11]. In addition, the social and health related benefits linked to digital technologies and connected devices in buildings should not be overlooked.

Figure 6. Image of connected devices. Source: Extracted from AzoBuild online article.

Electronics, IT equipment and miscellaneous electric loads

As energy efficiency of core building loads improves, further opportunities can be found in electronics, IT equipment and other miscellaneous electric loads. The US Energy Information Administration forecast that these loads would consume up to 50% of delivered electricity in residential and commercial buildings [15]. This makes electronics, IT equipment and other miscellaneous electric loads a viable avenue for energy efficiency and grid services. The focus of manufacturers is however on energy efficiency rather than grid services (automated Demand Response). The use of connected plugs could however allow these devices to be controlled as part of loadshedding or shifting initiatives.

It is important to note that, with the exponential increase of digitally enabled devices or appliances, there is a need to consider the increased energy needs of the data transfers and information processing infrastructure as more and more data needs to be processed and stored in real-time. In Germany, this increase is expected to reach 300 TWh by 2030 [9]. If current trends are maintained, the gains of digitalisation would only be significant for heating and cooling technologies/ strategies while smart lighting and other appliances gains could be offset by the energy needs for the additional communication and processing infrastructure [16].

3.3 Digitalisation attributes and adoption barriers

Based on the global analysis in the selected countries (USA, Germany, Sweden and the UK) the **key attributes** of a digitalised building include the following:

- Supports two-way connectivity and communication with devices, equipment, and appliances within the building, as well as the grid.

INFOBOX 1 Key digital technologies

HVAC, Water heating and Refrigeration

Building heating, ventilation, air conditioning, water heating and commercial refrigeration take up the largest share of electrical consumption in buildings, offering the greater opportunity for energy efficiency. These loads are highly shiftable due to thermal inertia making them the perfect candidate for automated grid service support with no to little impact on the occupant comfort. The performance is highly dependent on the climate and the building envelope – high performance in winter for cold climates and in summer for hot climates. Connected thermostat with additional external sensors (temperature, occupancy, etc.) linked to predicted daily temperature from offsite systems ensure an efficient process of these shed-able/shiftable loads within the building or the grid in which they operate.[12]

Connected lighting

Connected lighting refers to a system of light fixtures that have sensors and are connected to a network, allowing them to send and receive data based on pre- programmed schedule or automatic optimised control. The penetration of this technology is currently low – estimated at 4% for commercial US buildings for fixtures with a 2-ways communication capability. The control of these fixtures is mostly achieved by dimming the lights in commercial and industrial buildings when demand reduction is needed. The slow adoption of automated lighting (two-way connections) on a larger scale can be attributed to limited interest from manufacturers and developers that tend to focus on large commercial and industrial loads such as HVAC and water heating systems. Development of digitalisation in this technology area can only see growth once incentives such as cost and/or regulation provide the opportunities for compelling business cases. A large portion of the present connected lighting penetration in the US can be attributed to the introduction of a new building code in requiring that buildings above a certain square footage must be capable of automated wattage reduction of 15% [13].

Automated building envelope and windows

This englobes all technologies that can be used to regulate temperature and illumination in the building taking advantage of the external environment. Automating these technologies can considerably increase the energy efficiency of a building. Window and building envelop could affect up to 47% of overall electricity consumption in buildings depending on the climate [14]. Technologies in this category impact efficiency, load shedding (dynamic window glazing for lighting) and load shifting.

- Equipment within the system is designed to monitor, report, and provide flexibility to shed, shift, or modulate load by responding to control commands (locally or remotely).
- Ability to monitor, incorporate, predict, and learn from building-level conditions (occupant needs and preferences) and outdoor conditions (weather and grid needs).
- Co-ordinates and executes complex control strategies that adapt to changing conditions over multiple timescales.
- Quantitatively estimate and verify the energy and demand savings of different strategies and impacts from changing building conditions (e.g., occupancy behaviour due to the improvements).
- Optimization techniques can choose among multiple strategies and balance efficiency with flexibility and occupancy comfort.
- Inter-operability, having the ability to exchange data and control signals effectively and securely among connected devices/equipment/appliances and control systems.
- Resilient to ***cyberattacks*** and threats, having the ability to perform the services described above while maintaining end-to-end data security and protection against unauthorized access. The war in Ukraine confirmed the danger effects of these intimidations when executed under orders of high authorities.

Success of digitalisation adoption in the buildings sector is slowly building up. Barriers to a wider adoption of digital technologies have delayed its development even in the most advanced countries. In countries such as **Sweden** with one of the highest digitalisation maturities in Europe, the focus of digitalisation in the energy sector has been on energy intensive industries including manufacturing and industrial processes seen as sectors with most opportunity in energy savings and demand response [11]. Some observed **barriers** include:

- **Consumer perception**: new and mostly unproven digital technologies receive resistance from users due to lack of understanding of the technology and concerns over information security [7]. Most connected devices have yet to receive wide adoption as only limited data and case studies are available for the wider public
- **Complexity**: connected devices developed by multiple players in the market use different data management and communication protocols – mostly proprietary – hindering the interoperability of the devices [2].
- **Business models**: high initial costs, low customer participation and limited commercial incentives are disadvantages in developing new business models. Digitalisation tends to disproportionally benefit the building tenants through decreasing energy bills, operational costs and carbon footprints. At the same time the building occupants/employees are furthered by better healthy living and working conditions, while assisting the greater productivity or quality of life. However, the building owner, who ultimately invests in the digital technologies, sees very little return on investment in the short term.

In addition to these barriers, there is a need to develop the infrastructure necessary to process the volume of data generated by connected devices at a scale never seen before and ensure that there is sufficient skill in the operation and maintenance of the considerable large ICT infrastructure, as well as data analytics and data science in general. The impacts of these barriers could however be mitigated by [9]:

- Standardizing energy efficient digital technologies through proven and measured benefits to provide transparency e.g., energy performance labelling.
- Provide clear data security standards and policies for building digital technologies.
- Use of open data management and communication protocols to ensure interoperability of digital devices from different providers.
- Energy services providers to offer demonstration platforms.
- Ensure transparency on issues encountered during development of digital technologies, identified solutions and performance metrics.
- Government to provide subsidies and continuous support on building digitalisation such as split incentive between tenant and owner so benefits can be shared by both.
- Create market regulations to facilitate new business models.
- Support investment in development of ICT infrastructure while training a new type of workforce that would be able to operate and maintain the infrastructure.
- Develop innovative and creative Digitalisation Awareness Campaigns – conventional communication channels and strategies will just not work in this instance!

In summary, technologies, and know-how necessary to digitalise energy use in buildings is present in developed markets but wide adoption is still hindered by the above-mentioned factors.

3.4 Digitalisation risks

Although the benefits of digitalisation for businesses in reducing their operating costs have been made clear above, there are still some risks associated with the implementation of digital technologies as part of an active strategy for utility management in buildings. These are:

1. **Cyber security**: This is a growing concern for any business and with the growing trend of digitalisation in the energy sector, cyber security should be taken much more seriously by building and facility managers. If the restricted building network is

unauthorizedly penetrated by one reason or another, this could be more harmful now that most systems are interconnected. Additionally, access to the building local network could provide "intruders" with access to control physical system with the potential to cause physical harm to the building occupants.

2. **Complexity:** Due to the interconnectivity of the digital system, the entire system would be much more difficult to manage and that could present opportunity for "intruders" to find weaknesses in the complex system. In addition, improper management of the complex system could reduce the efficiency of the building operation instead of improving it.

3. **Personal data management:** With the interest of improving operation, digital system might collect some personal information of employees. However, any company and organization irrespective of the size, sector or location that process the personal information, should comply with the South Africa's Protection of Personal Information Act (POPIA) [17].

3.5 Digital solution providers with South African presence

Major international digitisation solution providers with an important South African presence have developed solutions tailored to the South African energy context. A non-exhaustive list of these major international players include:

Siemens: provides hardware and software for energy management devices and selected sensors. Specialised servers can be provided based on needs and buildings specification

- **Schneider Electric** provides hardware and software for energy management devices and selected sensors. Specialised servers can be provided based on needs and building specification
- **Rockwell automation:** dedicated to automation, provides a variety of smart devices for building and industrial application. They also offer remote access to plant floor data via smartphone, tablets, or laptop
- **IFM electronics:** Provide a variety of high-quality sensors used in data collection and automatic control.

Other international major players in digitalisation includes Cisco Systems Inc., IBM Corporation, Microsoft Corporation with greater focus on IoT, data analytics and cloud computing.

In addition, local digitisation solution providers, partnering with international players are also actively developing solutions for digitalisation of buildings. Some of these local players include:

- **Customized Control Solutions**: provides hardware and software for energy management devices and selected sensors. Custom built systems based on Tridium, Siemens, Sedona and Alerton platforms can be provided. Target market is the commercial and hospitality sectors of the economy.

- **Solid State Controls**: provides hardware and software for energy management devices and selected sensors. The company provides complete solutions and can design room controls, plant controls, monitoring systems which are interactable with Honeywell, Tridium and Alerton platforms. Target market is the commercial and hospitality sectors of the economy.
- **Optimal Control Systems:** provides hardware and software for energy management devices and selected sensors. The company provides complete solutions able to integrate various measurement devices such as temperature sensors, airflow pressure switches, metering, various speed drives, air quality, access control etc which are interactable with Honeywell, Distech, Johnson Controls, Tridium and Alerton platforms. Target market is the commercial and manufacturing sectors of the economy.
- **PCS Global**: provides hardware and software for energy management devices and selected sensors. The company provides complete solutions based on SCADA systems and automatic controls from design, implementation, testing, and monitoring. The company has a footprint in the entire southern Africa region.

From the global analysis, there is tremendous potential in energy saving and optimisation through digitalisation of energy systems in the buildings sector. This is evidenced by the growing interest of governments and private organisations and the development of new business cases taking advantage of the possibilities provided by digital technologies in energy efficiency initiatives. Digitalising energy management is seen as the next step towards a zero-carbon future for many countries. However, significant challenges must be addressed at different levels including technology compatibility, cost, regulations and the public adoption of this new technologies. In addition, the COVID- 19 pandemic and its devastating secondary impacts on the South African economy, created wide avenues for utilizing the enormous potential of the digitalisation of buildings as a part of revitalisation / normalisation of South African and world's economies.

4. Digitalisation – the South African context

In contrast to the building digitalisation boom in other countries, the main *challenge* for digital transformation in South Africa is the ***availability of reliable electricity supply***, which is as a result of the shortage of generation capacity in the country. From the local context, the availability of electricity is the main focus for government and policy makers, and this is reflected on the digital technologies that are prioritised in building energy management. Here, efficient operation from device to system level in buildings is the emphasis as evidenced by the new EPC regulation [18] while grid integration is still decades away. This is a result of, primarily, the lack of sufficient generating capacity and secondly, lack of the necessary infrastructure to provide grid integration services to buildings.

Therefore, in the South African conditions, one of the main KPIs for buildings digitalisation will be the ability of the business processes to be unaffected by the regular (planned and non-planned) electricity outages.

Under the recent EPC regulations, buildings in South Africa need to have their energy performance assessed by an accredited party, which will issue an EPC that rates the building in terms of energy efficiency. The energy performance is defined in the regulations as the net energy consumed in kilowatt-hours per square meter per year ($kWh/m^2/yr$) to meet the different needs associated with the use of a building. These regulations are expecting to boost the process of a building digitalisation and associated energy efficiency initiatives.

Considering the share of electrical consumption in buildings, digitalisation offers immense opportunities for improving the energy balance challenges of the country. The main contributions of the digitalised buildings in this regard are:

- Reducing the energy demand and the base load by energy efficiency and renewable energies.
- Intelligent real-time load control at the peak periods for cost reduction to the user and better system operation for the grid operator.
- Allowing co and self-generation with options to export the excess of the locally generated electricity back to the national grid.
- Improving the carbon footprint of the country due to enhanced energy efficiency, energy & water storage, recycling and extensive usage of renewable energy sources.
- Creating awareness and educating building occupants on energy efficiency and sustainable behaviour at work and at home.

In addition, expanding buildings digitalisation could contribute to the mitigation of the secondary impacts of COVID-19 pandemic on the South African economy. The main result would be the creation of "green" jobs based on advanced technologies for the digitalisation of buildings. It should be noted that most of the above jobs would be based on advanced computing technologies, laptops, tablets and other mobile "smart" devices, thus easily accessible to the younger generations generally more "tech savvy" and people with disabilities due to remote access and control capabilities.

4.1 Data collection methodology

The objective of the data collection was to provide an overview of:

- the digital adoption/ digital maturity in the buildings sector in South Africa from a private and public sector regulatory framework perspective.
- the digital trends in the South African buildings sector.
- the existing regulatory framework/ national strategic documents and assess the potential impact of COVID-19 on the developments.

This will then allow the compilation of the key opportunities of digitalisation for the buildings sector, focussing on energy efficiency/savings potential and additional job opportunities.

The relevant primary data was obtained directly by Qualitative Data Collection Techniques (QDCT) which included visits, observations, interviews and questionnaires.

The following building types were selected in order of priority for the study:

1. Office buildings (government, corporate, municipal)
2. Commercial buildings (shopping centres, warehouses, hotels)
3. Places of instruction (universities, colleges etc.)
4. Hospitals and clinics

These buildings were expected to present the largest impact and opportunity for the advantages of digitalisation. The aim of the study was to identify a minimum of 5 and a maximum of 10 buildings per type. Provisions were made such that representative group of different types of buildings as per the occupancy categories (per building classification for each climatic zone) listed in SANS 10400-XA:2021: The application of the National Building Regulations [14] is represented in the selection as realistically as possible. In COVID-19 working environment the Team focus was on on-line and remote avenues for data collection.

INFOBOX 2 Building classifications

A1: Entertainment and public assembly occupancy where persons gather to eat, drink, dance or participate in other recreational activities. This occupancy includes venues such as restaurants, night clubs, sport bars, gyms, and other similar venues. In South Africa, these venues are mostly found within larger buildings or complexes such as shopping centres and malls and thus depends on utility provided by these centres including electricity, water, refuse, or backup power. This limits the ability of tenants within this occupancy type to invest in technologies (digital or otherwise) to reduce their utility cost if not implemented by the commercial centre.

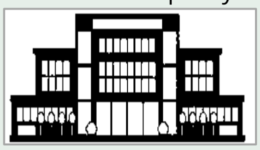
A2: Theatrical and indoor sport occupancy where persons gather for the viewing of theatrical, operatic, orchestral, choral, cinematographically or sport performances. This includes movie theatres, live theatre, or sport courts. These venues are mostly found within larger buildings or complexes such as large commercial centres and malls; however, they occupy a lager footprint as compared to the A1 occupancy venues and have a bigger sway with the centre facility management or landlords to independently manage their utility costs. This is achieved through sourcing of alternative supply (renewable and/or backup power) or through more sophisticated utility cost management processes including digital technologies within the area they occupy.

A3: Places of instruction occupancy where school children, students or other persons assemble for the purpose of tuition or learning. It includes occupancy other than primary or secondary schools where students or other persons assemble for the purpose of tuition or learning. This would, therefore, include schools, colleges, universities, and Technikons. Usually as multiple buildings on a campus, the A3 occupancy type offers great opportunities for optimisation through digitalisation. This could include the optimal management of appliances based on different utilisation patterns of auditorium, offices and lecture halls or optimal control of backup generation and renewable generation (if applicable).

F1: Large shop occupancy where merchandise is displayed and offered for sale to the public and the floor area exceeds 250 m². Venues in this occupancy type could be located within larger commercial centres or as standalone buildings. The important footprint of these venues within commercial centres provides sufficient leverage with the centre management to operate and manage their own utility cost through optimised control and process. This mainly includes lighting and climate control, optimising the customer experience and energy costs. Standalone facilities in this category are also incentivised to manage their utility to optimise operating costs. These standalone facilities often take advantage of their large footprint to generate and store electricity on site in addition to managing their other utility cost via digital technologies.

F2: Small shop occupancy where merchandise is displayed and offered for sale to the public and the floor area does not exceed 250 m². Mostly found within larger buildings or complexes such as commercial centres and thus depends on utilities provided by these centres (electricity, water, refuse, etc). This limits the ability of buildings in this occupancy type to invest in technologies (digital or otherwise) to reduce their utility cost if not implemented by the centre as a whole.

F3: Wholesaler's store occupancy where goods are displayed and stored and where only a limited selected group of persons is present at any one time. Somewhat similar to the F1 large shop occupancy class, these buildings are mostly standalone construction and rarely found within large commercial centres. The same incentive as for the F1 occupancy class apply for this class.



G1: Offices Large multi-story office buildings, banks, consulting rooms and similar uses with lifts and energy consuming services that operate on a typical daytime occupancy. Buildings in this type of occupancy are more likely to invest in technologies aimed at reducing their utility cost. Businesses that operate in venues of this occupancy type are more likely to have the capital of financing opportunities to invest in digital technology for utility cost optimisation and to ensure uninterrupted electrical supply.

G1: Offices stand-alone blocks or campus (or both) of buildings that form an office park but operate separately. A campus type occupancy offers a great opportunity for utility cost optimisation. Similar to the occupancy type A3: Places of instruction, the utility resources could be optimised according to utilisation pattern for each building in the campus.

H1: Hotel occupancy where persons rent furnished rooms, not being dwelling units. In this occupancy type, any interruption to utility services such as water and electricity will highly inconvenience guests and result in fewer bookings. As a result, important investments have been made in venues within this occupancy type to ensure uninterrupted electrical and water supply via storage, back-up generation and/or renewable generation on site where allowed by local regulation. This has also encouraged the adoption of digital technologies to manage and optimise the use of energy within these facilities to minimise cost end ensure reliability of the supply.

E2: Hospital occupancy where people are cared for or treated because of physical or mental disabilities and where they are generally bed-ridden. Many of the South African hospitals are well advanced in the building digitalisation. The uncertain electricity supply demanded 100% secure alternative electricity supply during the regular load shedding in the country. All the core technologies have been subject to control and optimization based on the principles of digitalisation. The Solar Water Heating and Photovoltaic (PV) alternative/ storage systems are available and in use. This allowed efficient operation, patient care and satisfaction especially in the critical times of the pandemic.

The classifications above were chosen based on anticipated matured levels of digital penetration in comparison with excluded building classifications. The study assumed that the excluded building classifications were not as digitally matured as the included building classifications. Further work is recommended to include the remainder of building classifications in future work.

4.2 Evaluation criteria

Based on the global analysis and on the specific South African focus of digitalisation, the following criteria were employed in the evaluation of digital technologies in energy management in buildings:

1. Digital technologies – assessing the type of digital technologies present within the building. This does not however indicate that the facility uses the digital technologies e.g., take advantage of advanced functionalities of connected devices for energy efficiency improvement.
2. Digital connectivity and communication – assessing the type of communication employed to monitor and control digital devices within the buildings.
3. Monitoring and reporting capabilities – assessing the quality and usability of the data collected by and from the digital technologies.
4. Remote control capabilities – assessing the automatic and remote-control capabilities of the digital devices.
5. Inter-operability – assessing the level of inter-operability amongst the different digital devices in the building.
6. Data management and security – assessing the data management and security level of the digital information collected.

For each of the above criteria, the building was rated on a scale from 0 to 5.

4.3 Sample size

The actual sample size per building classification is presented below. The minimal sample size was reduced from 5 to 3 with the aim of still capturing diversity in results. Additionally, the buildings targeted in most instances are assumed to have multiple identical establishments throughout the country e.g., business chains, franchises, and multi-located establishments.

Table 1. Sample size

Clusters Classification of Building occupancy and Building Description in accordance with SANS 10400-XA:2021	Sample size
A1: Entertainment and public assembly Occupancy where persons gather to eat, drink, dance or participate in other recreation	5
A2: Theatrical and indoor sport Occupancy where persons gather for the viewing of theatrical, operatic, orchestral, choral, cinematographically or sport performances	2
A3: Places of instruction Occupancy where school children, students or other persons assemble for the purpose of tuition or learning	5
F1: Large shop Occupancy where merchandise is displayed and offered for sale to the public and the floor area exceeds 250 m²	5
F2: Small shop Occupancy where merchandise is displayed and offered for sale to the public and the floor area does not exceed 250 m²	5
F3: Wholesaler's store Occupancy where goods are displayed and stored and where only a limited selected group of persons is present at any one time	**5**
G1: Offices Large multi-story office buildings, banks, consulting rooms and similar uses with lifts and energy consuming services that operate on a typical daytime occupancy.	**5**
G1: Offices Stand-alone blocks or campus (or both) of buildings that form an office park but operate separately	**5**
H1: Hotel Occupancy where persons rent furnished rooms, not being dwelling units	**5**
E2: Hospital Occupancy where people are cared for or treated because of physical or mental disabilities and where they are generally bed-ridden.	**5**

4.4 Digital penetration scores

The scoring per building classification is presented in **Error! Reference source not found.**. Depending on the answer to each question out of the questionnaire, a score for digital maturity is attributed to every building. The higher the perceived digital maturity of the building is, the higher the building scores. Each assessed building is scored out of a total of 30 points. Based on the final score, the following 5 bands of digital maturity/penetration have been defined:

Between 0 and 5: Building has **minimal digital penetration**

1. Between 5 and 10: Building has **some digital penetration**
2. Between 10 and 15: Building has **average digital penetration**
3. Between 15 and 23: Building has **digital penetration above average**
4. Greater than 23: Building has **matured digital penetration**

Table 2. Digitalisation scores

Building Evaluation Matrix based on the Assessment Questionnaire			
Building Score Margins	**From**	**To**	**Building Performance Score Assessment**
Between 0 and 5:	0%	17%	Building has ***minimal digital penetration***
Between 5 and 10:	17%	33%	Building has ***some digital penetration***
Between 10 and 15:	33%	50%	Building has ***average digital penetration***
Between 15 and 23:	50%	77%	Building has ***above average digital penetration***
Greater than 23:	77%	100%	Building has ***matured digital penetration***

Table 3. Digital penetration scoring per assessed building

	Digital technologies	Digital connectivity and communication	Monitoring and reporting capabilities	Digital devices / Equipment Inter-operability	Control Capabilities	Data management and security	Total score /30	Penetration level
A1: Entertainment and public assembly occupancy where persons gather to eat, drink, dance or participate in other recreation	2	1	1	1	1	0	6	Some digital penetration
	2	1	1	1	1	0	6	Some digital penetration
	1	1	1	1	1	0	5	Some digital penetration
	2	1	1	1	1	0	6	Some digital penetration
	3	2	1	1	1	0	8	Some digital penetration
A2: Theatrical and indoor sport occupancy where persons gather for the viewing of theatrical, operatic, orchestral, choral, cinematographically or sport performances	4	2	1	1	1	1	10	Some digital penetration
	4	4	1	1	2	1	13	Average digital penetration
A3: Places of instruction occupancy where school children, students or other persons assemble for the purpose of tuition or learning	1	3	3	1	1	4	13	Average digital penetration
	3	1	1	1	0	0	6	Some digital penetration
	4	2	1	1	1	0	9	Some digital penetration
	4	1	1	0	1	0	7	Some digital penetration
	4	1	1	1	0	0	7	Some digital penetration
F1: Large shop occupancy where merchandise is displayed and offered for sale to the public and the floor area exceeds 250 m²	0	1	1	1	1	0	4	Minimal digital penetration
	4	2	1	1	2	1	11	Average digital penetration
	4	2	1	1	2	1	11	Average digital penetration
	3	2	3	1	1	4	14	Average digital penetration
	4	5	5	4	4	5	27	Mature digital

								penetra-tion
F2: Small shop occupancy where merchandise is displayed and offered for sale to the public and the floor area does not exceed 250 m²	1	1	1	1	2	0	6	Some digital penetration
	1	1	1	1	1	1	6	Some digital penetration
	1	1	1	1	1	1	6	Some digital penetration
	2	1	1	1	1	1	7	Some digital penetration
	2	1	1	1	1	1	7	Some digital penetration
F3: Wholesaler's store occupancy where goods are displayed and stored and where only a limited selected group of persons is present at any one time	2	2	1	1	1	0	7	Some digital penetration
	2	1	1	1	1	0	6	Some digital penetration
	2	2	1	1	1	0	7	Some digital penetration
	5	3	3	2	3	4	20	Above average digital penetration
	1	1	1	1	1	1	6	Some digital penetration

4.5 Digital penetration score per occupancy type

It is assumed that each assessed building's score weighs equally in the overall assessment per building category. It is for this reason that increasing the sample size will affect the results linearly and marginally regardless of building size and numeracy e.g., franchises of the same design could have the same scoring and skew the results to their favour if identical buildings were chosen for analysis. Table represents the score per digitalisation transformation criteria for each building surveyed. The total score is then taken as the average for each occupancy class surveyed**.**

The penetration level for each occupancy type assessed is shown in Error! Reference source not found.**7**. Overall, **large o ffice building** occupancies demonstrate the **highest level** of digital penetration for energy management. In fact, it is the only occupancy type from the buildings sample surveyed that has a **mature penetration** score.

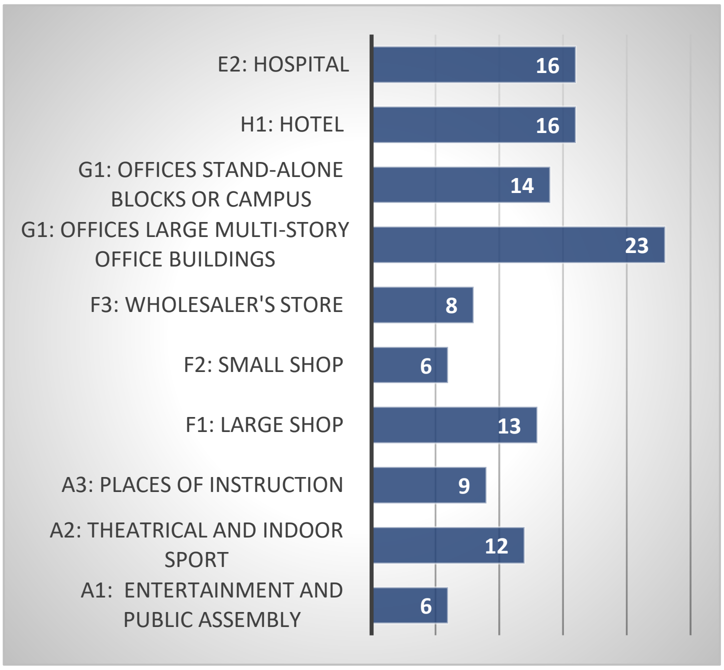


Figure 7. Digitalisation summary across surveyed occupancy classes

This is followed by hospital and hotel occupancies with above average scores. Small offices, large shops, theatrical and indoor sport occupancy types follow with average penetration scores and the remaining occupancies scoring below average or with some digital penetration. It is interesting to notice that none of the surveyed buildings scored a minimal digital penetration score showing the reach digital technologies have had in the operation of buildings across all building occupancy classes.

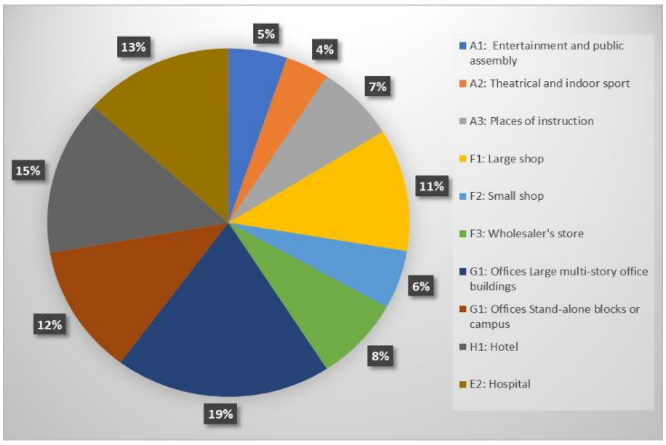


Figure 8. Contribution to overall scoring

There is a clear indication that buildings within occupancy types with easier access to opportunities or with the right incentives to "digitalise" have the highest penetration according to the surveyed buildings. Large office occupancies have **easier access to funding** for digitalisation while the operating efficiency of hospitals and hotel, directly linked to the **capacity to stay competitive**, is greatly enhanced by digital technologies.

Error! Reference source not found.**8** shows the contribution o f each occupancy type to the total performance of the surveyed South African buildings (based on a weighted average score). The G1 large office occupancy contributes 19% while the A1, A2, and F6 occupancy classes contribute 6% or below.

This shows that a fifth of the overall digital penetration in South African buildings can be attributed to large office occupancy building types.

Looking at a more detailed analysis of the collected data as shown in Error! Reference source not found.**9**, the contribution of each digital transformation criteria to the overall scoring of each occupancy type is indicated.

Error! Reference source not found. shows the overall contribution of each criterion to the scoring of the surveyed buildings in the South African context. About a third of the contributing criteria is the technologies installed on site while the lowest contributing criteria are data management and security, and inter-operability of digital technologies.

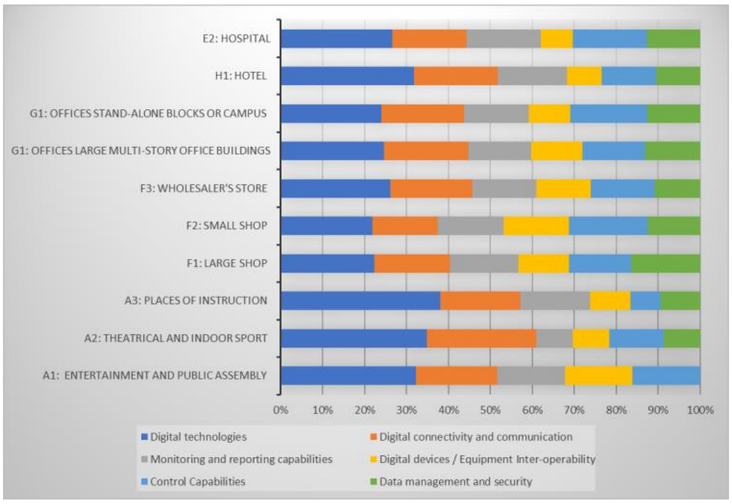


Figure 9. Detailed digital penetration analysis

The analysis shows that the penetration for each occupancy type is **skewed towards the digital technologies** criteria while the inter-operability and data management, and security criteria contribute less across all occupancy types. This reveals a trend where digital technologies are installed but not utilised as intended due to either **lack of the necessary infrastructure or lack of expertise to operate** the connected technologies within the buildings. This is quite evident in the place of instruction occupancy type where about 40% of digital penetration is due to the installed digital technologies while inter-operability, data management and security, and control contribute for less than 30%. Note that for A1 occupancy types there was no evidence of data security and management processes.

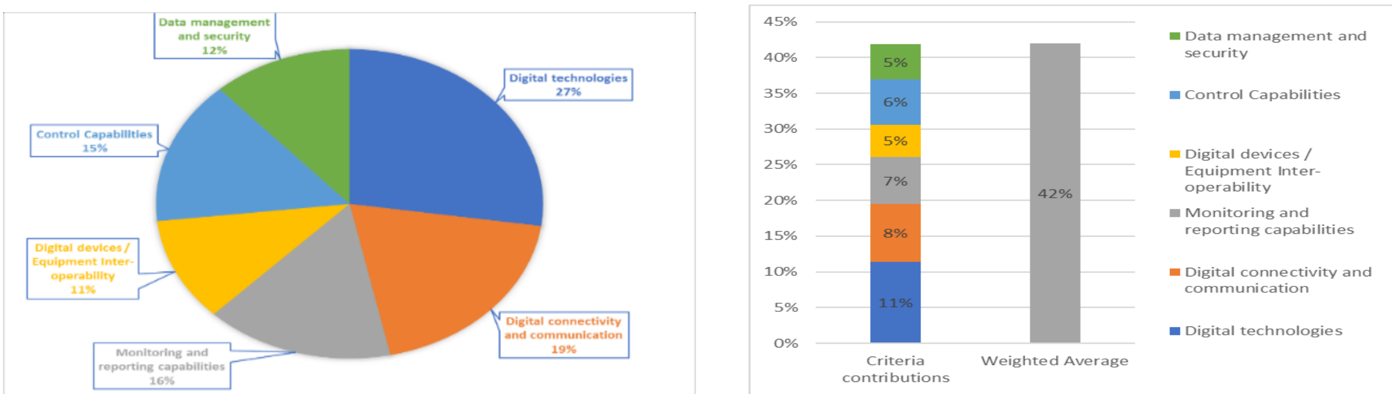


Figure 10. Overall contribution per criteria – South Africa survey

5. Buildings digitalisation penetration in other markets

Green Building Councils (GBCs) are independent, non-profit organizations made up of businesses and organizations working in the building and construction industry. The mandate of GBCs is to inspire a built environment where people and planet thrive. To promote, encourage and facilitate green building in the property and construction industry through market-based solutions, by promoting the practice of green building and sustainable living.

One of the tools used by the GBCs is the LEED® rating system [19]. The LEED® rating system has seven areas of concentration, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design process and regional priority. Projects obtain credits in these areas to achieve certification. Certification status is based on 5 levels namely Certified (up to 49 points), Silver (up to 59 points), Gold (up to 79 points) and Platinum status (more than 79 points).

5.1 Digital penetration scoring (global equivalent results)

To align the study ratings with the council ratings, it has been assumed that the percentage points of the LEED tool and the local study questionnaire align in terms of percentages. This means that the global adaptation of the local study can be realized using **Error! Reference source not found.**. This assumption is because higher rating on the LEED ranking requires higher level of digital technology to meet the stringent criteria of the global scale. The adaptation matrix assumes that the scoring assessment in the global study was not focusing only on areas of concentration depicted above but a focus on energy management and efficiency as a main theme.

Table 4. LEED tool to local study equivalence

Global Scoring			**Local South African Equivalent**
Platinum		80+ points earned	Advanced digital penetration
Gold		60-79 points earned	Above average digital penetration
Silver		50-59 points earned	Average digital penetration
Certified		40-49 points earned	Some digital penetration

The Green Building Council global directory of projects was reviewed and building categories in the directory paired to the SANS 10400-XA:2021 categories for ease of comparison.

Buildings not registered on the LEED database are less likely to have a building with significant advancement in digital technologies. We acknowledge that this might skew the global finding towards higher penetration, however, the local study did not find any of the buildings surveyed to have minimal digital penetration allowing to draw an equivalence or comparison between the LEED database to the local study.

5.2 Digital penetration scoring - United States of America

The United States has approximately 35,454 buildings listed across the 10 building classifications with various levels of certification as shown in Error! Reference source not found.. B uildings with the greatest number of platinum certification/mature digital penetration are predominately in the G1: Offices large multi-story office buildings followed by the A3: Places of instruction category. This is expected since corporations are perceived to have the funds that can be deployed to undertake such exercises and learning institutions are at the forefront of technological innovation. Energy consumption is also the key driver to obtain certification as well as maintaining branding recognition.

Table 5. Digital penetration results - United States

Building classification	Certified / Some digital penetration	Silver / Average digital penetration	Gold / Above average digital penetration	Platinum / Advanced digital penetration	Grand Total
A1: Entertainment and public assembly	1306	1185	909	123	3525
A2: Theatrical and indoor sport	43	85	76	11	215
A3: Places of instruction	917	2605	3022	481	7026
E2: Hospital Occupancy	328	553	409	41	1331
F1: Large shop Occupancy	1810	1235	730	72	3847
F2: Small shop Occupancy	18	12	10	0	40
F3: Wholesaler's store	434	488	274	27	1223
G1: Offices Large multi-story	2880	5227	6710	1203	16020
G1: Offices Stand-alone	213	306	394	65	978
H1: Hotel Occupancy	254	557	399	39	1249
Grand Total	**8203**	**12253**	**12933**	**2062**	**35454**

5.3 Digital penetration scoring - United Kingdom

The United Kingdom has 152 Green Building Council certified buildings. Like the United States the trend for the buildings with the highest rating is in the G1: Offices large multi-story office buildings sector however, followed by the F1: Large shop occupancy building classification. This could be attributed to the fact that the G1: Offices large multi-story office buildings category comprises of corporates that have the financial means to implement energy efficiency measures while simultaneously obtaining reputational capital.

Table 6. Digital penetration results – United Kingdom

Building classification	Certified / Some digital penetration	Silver / Average digital penetration	Gold / Above average digital penetration	Platinum / Advanced digital penetration	Grand Total
A1: Entertainment and public assembly	8	2	4	0	14
A2: Theatrical and indoor sport Occupancy	0	0	0	0	0
A3: Places of instruction	0	0	1	1	2
F1: Large shop Occupancy	13	4	3	2	22
F2: Small shop Occupancy	11	3	11	1	26
F3: Wholesaler's store	0	0	1	0	1
G1: Offices Large	7	14	42	15	78
G1: Offices Standalone	0	0	1	0	1
H1: Hotel Occupancy	1	0	3	4	8
Grand Total	**40**	**23**	**66**	**23**	**152**

5.4 Digital penetration scoring – Germany

Green Building Council of Germany has 450 certified buildings. G1: Offices large multi-story office buildings classification is the largest category of platinum certified/mature penetration scoring. Similar to the other markets, this category comprises of corporates with financial means to support digitalisation.

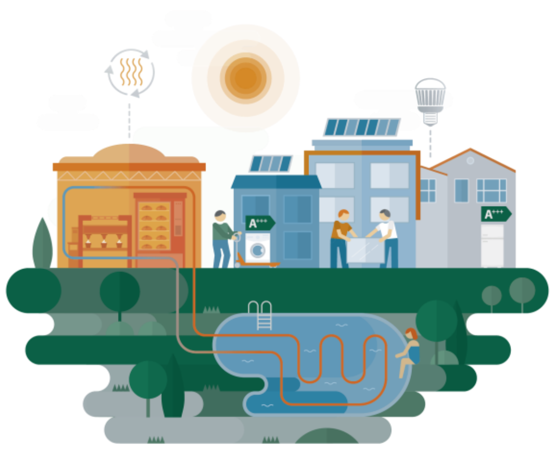


Table 7. Digital penetration results - Germany

Building classification	Certified / Some digital penetration	Silver / Average digital penetration	Gold / Above average digital penetration	Platinum / Advanced digital penetration	Grand Total
A1: Entertainment and public assembly	9	0	9	0	18
A3: Places of instruction	0	10	5	1	16
E2: Hospital Occupancy	0	3	1	0	4
F1: Large shop Occupancy	12	3	5	7	27
F2: Small shop Occupancy	7	2	7	0	16
F3: Wholesaler's store	0	1	4	0	5
G1: Offices Large	2	18	246	62	328
G1: Offices Standalone	1	0	1	1	3
H1: Hotel Occupancy	0	6	26	1	33
Grand Total	**31**	**43**	**304**	**72**	**450**

5.5 Digital penetration scoring – Sweden

The Green Building Council of Sweden has 218 certified buildings across 9 building classifications that are applicable to this study. G1: Offices large multi-story office buildings have the highest representation in the platinum / matured penetration level. This could be because of the availability of funds to conduct energy efficiency projects being accessible in this sector as well as adopting trends from other countries with regards to certification.

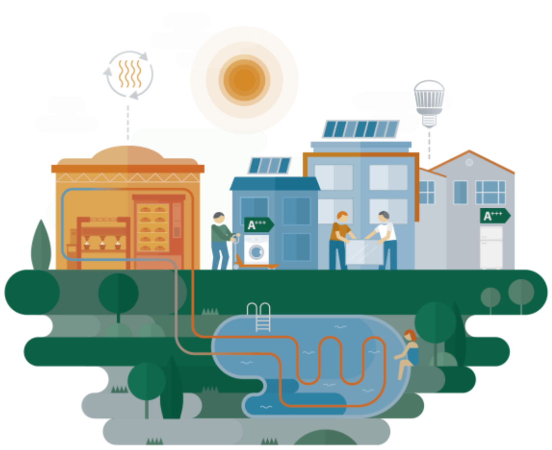


Table 8. Digital penetration results - Sweden

Building classification	Certified / Some digital penetration	Silver / Average digital penetration	Gold / Above average digital penetration	Platinum / Advanced digital penetration	Grand Total
A1: Entertainment and public assembly	0	0	3	0	3
A3: Places of instruction	1	1	4	0	6
E2: Hospital Occupancy	0	2	19	1	22
F1: Large shop Occupancy	1	1	16	1	19
F2: Small shop Occupancy	1	1	0	0	2
F3: Wholesaler's store	0	3	4	0	7
G1: Offices Large	2	8	97	42	149
G1: Offices Stand-alone	0	1	0	0	1
H1: Hotel Occupancy	0	0	7	2	9
Grand Total	**5**	**17**	**150**	**46**	**218**

6. Digital penetration comparison (local results vs global results)

Local results have been compared to global results as per the **Tables 8, 9, 10 and 11**. Where data is not available for a building classification this has been indicated as such. Developed countries' digital penetration levels in most building classifications are **predominately higher than their local counterparts** with a few exceptions. At this stage, a few possible reasons can be suggested such as:

- Local buildings need to be more energy resilient to cater for instances such as load shedding or instances of poor quality of supply.
- Occurrence of incentive schemes such as Eskom's EEDSM program has aided the building sector to drive change.
- Most of the building occupants are tenants, and the uncertainty with short-term renting contracts is a serious obstacle for businesses to invest in building digitalisation / improvements. This, combined with the regular electricity supply interruptions, forces the business to invest in stability of supply (back-up generation) rather than seeking sustainable and long-term energy efficiency solutions. It is business survival preference to invest in availability of the electricity supply (now) rather than in energy efficiency (in a long run).

Relatively high consumer energy price increases have encouraged adaptation of digital systems to mitigate high utility bills. However, short-term solutions were adopted, rather than long-term sustainable energy efficiency interventions.

Series of Tables (9&10). Local results vs global results

Table 9	Penetration level local study	Penetration level United States of America
A1: Entertainment and public assembly	Some digital penetration	Above average digital penetration
A2: Theatrical and indoor sport Occupancy	Average digital penetration	Above average digital penetration
A3: Places of instruction	Some digital penetration	Above average digital penetration
E2: Hospital Occupancy.	Above average digital penetration	Above average digital penetration
F1: Large shop	Average digital penetration	Above average digital penetration
F2: Small shop	Some digital penetration	Above average digital penetration
F3: Wholesaler's store	Some digital penetration	Above average digital penetration
G1: Offices Large	Mature digital penetration	Above average digital penetration
G1: Offices Standalone	Average digital penetration	Above average digital penetration
H1: Hotel	Above average digital penetration	Above average digital penetration

6.1 Digital penetration comparison - Local study vs United States of America

The digital penetration of the assessed buildings occupancy types in the USA mirrors, largely, the relative level as seen in South Africa. Only that the maturity level is overall higher in the USA as illustrated in **Figure** . This shows that both the USA and South Africa focus the digitalisation efforts on corporate buildings, hospitality and health sectors. However, we should note that the sample size of the USA data is much larger that the local study and should appear more averaged than the local study results. The A3 occupancy is however an outlier in this comparison as places of instruction in the USA are extremely advanced when compared to the local findings. This could be linked to the availability of funding for operational optimisation in the mostly privatised high education sector in the USA.

Table 10.	Penetration level local study	Penetration level United Kingdom
A1: Entertainment and public assembly	Some digital penetration	Above average digital penetration
A2: Theatrical and indoor sport Occupancy	Average digital penetration	Not assessed
A3: Places of instruction	Some digital penetration	Mature digital penetration
E2: Hospital Occupancy.	Above average digital penetration	Not assessed
F1: Large shop	Average digital penetration	Above average digital penetration
F2: Small shop	Some digital penetration	Above average digital penetration
F3: Wholesaler's store	Some digital penetration	Mature digital penetration
G1: Offices Large	Mature digital penetration	Above average digital penetration
G1: Offices Standalone	Average digital penetration	Mature digital penetration
H1: Hotel	Above average digital penetration	Mature digital penetration

6.2 Digital penetration comparison - Local study vs United Kingdom

In the United Kingdom, the scoring is consistently mature and above average levels in all categories as seen in **Figure** . Offices, hotels, wholesaler shops, places of instruction and hospitals occupancies appear to be at mature while the remaining occupancies are above average level. The overperformance of large office buildings occupancy surveyed in the South African context as compared to the UK score in the same category is a result of the sampling size differences between the two data sets.

6.3 Digital penetration comparison - Local study vs Germany

In Germany, the scoring is quite consistent at mature and above average levels, in the same vein as in the UK. This shows a focus to digitalise multiple buildings categories as in the UK as shown in **Figure 12**. The overperformance of large office buildings occupancy surveyed in the South African study as compared to the German score in the same category could be explained by the smaller sampling size in the local study.

6.4 Digital penetration comparison - Local study vs Sweden

In Sweden, the digital penetration for building energy efficiency is at above average level across the board. Only the F2 and G1 standalone office occupancy types score in the average range. **Figure 13** shows a consistent penetration across all sectors in the Swedish market.

Series of Tables (11&12). Local results vs global results

Table 11.	Penetration level local study	Penetration level Germany
A1: Entertainment and public assembly	Some digital penetration	Above average digital penetration
A2: Theatrical and indoor sport Occupancy	Average digital penetration	Not assessed
A3: Places of instruction	Some digital penetration	Above average digital penetration
E2: Hospital Occupancy.	Above average digital penetration	Above average digital penetration
F1: Large shop	Average digital penetration	Above average digital penetration
F2: Small shop	Some digital penetration	Above average digital penetration
F3: Wholesaler's store	Some digital penetration	Above average digital penetration
G1: Offices Large	Mature digital penetration	Mature digital penetration
G1: Offices Standalone	Average digital penetration	Above average digital penetration
H1: Hotel	Above average digital penetration	Above average digital penetration

Table 12.	Penetration level local study	Penetration level Sweden
A1: Entertainment and public assembly	Some digital penetration	Above average digital penetration
A2: Theatrical and indoor sport Occupancy	Average digital penetration	Not assessed
A3: Places of instruction	Some digital penetration	Above average digital penetration
E2: Hospital Occupancy.	Above average digital penetration	Above average digital penetration
F1: Large shop	Average digital penetration	Above average digital penetration
F2: Small shop	Some digital penetration	Average digital penetration
F3: Wholesaler's store	Some digital penetration	Above average digital penetration
G1: Offices Large	Mature digital penetration	Mature digital penetration
G1: Offices Standalone	Average digital penetration	Above average digital penetration
H1: Hotel	Above average digital penetration	Mature digital penetration

Series of Figures. Local results vs global results

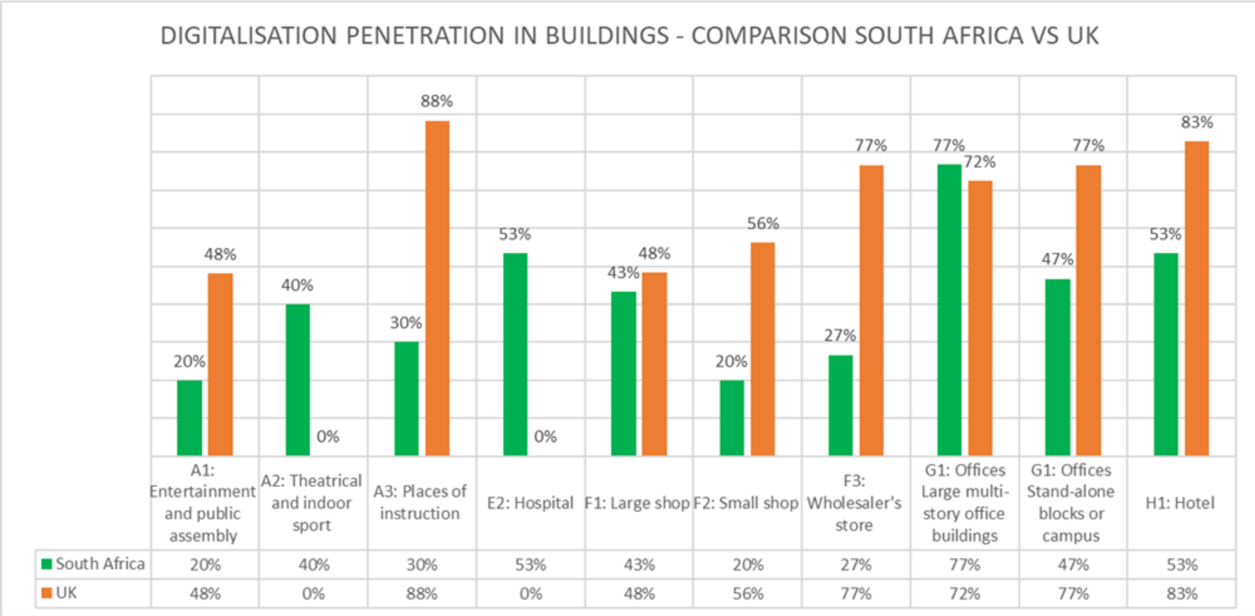


Figure 11. Digitalisation penetration in buildings - South Africa vs UK comparison

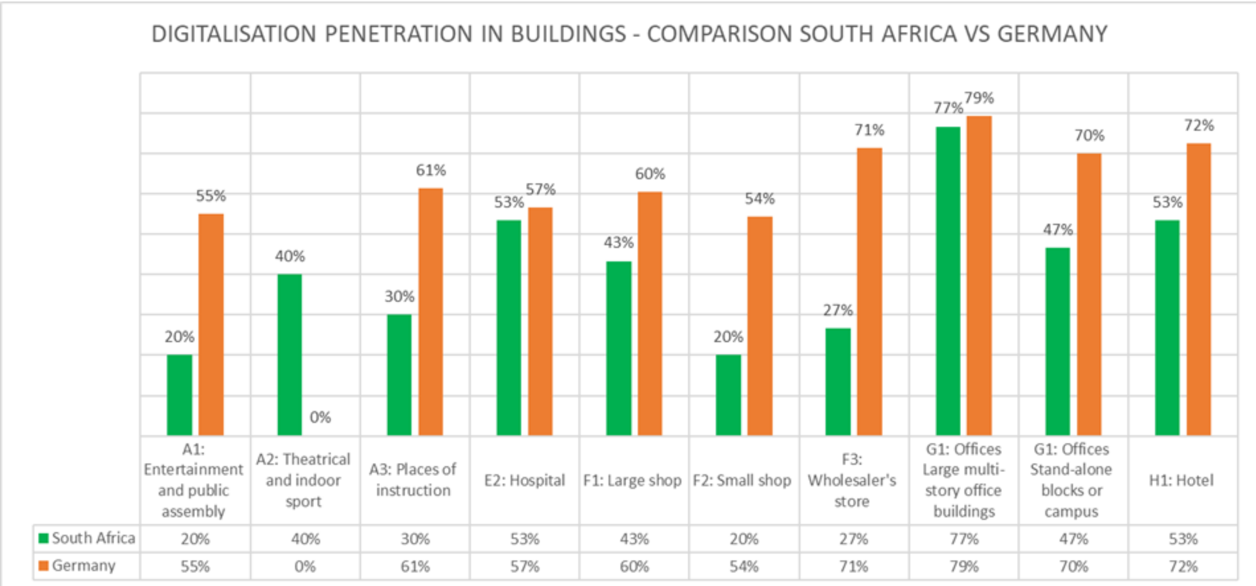


Figure 12. Digitalisation penetration in buildings - South Africa vs Germany comparison

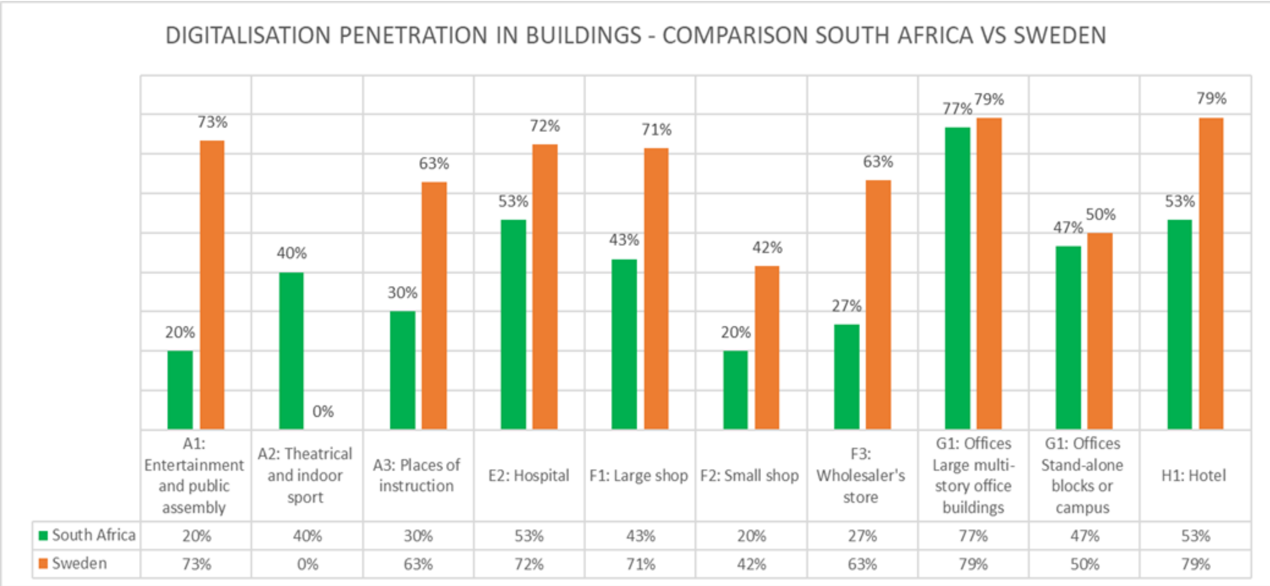


Figure 13. Digitalisation penetration in buildings - South Africa vs Sweden comparison

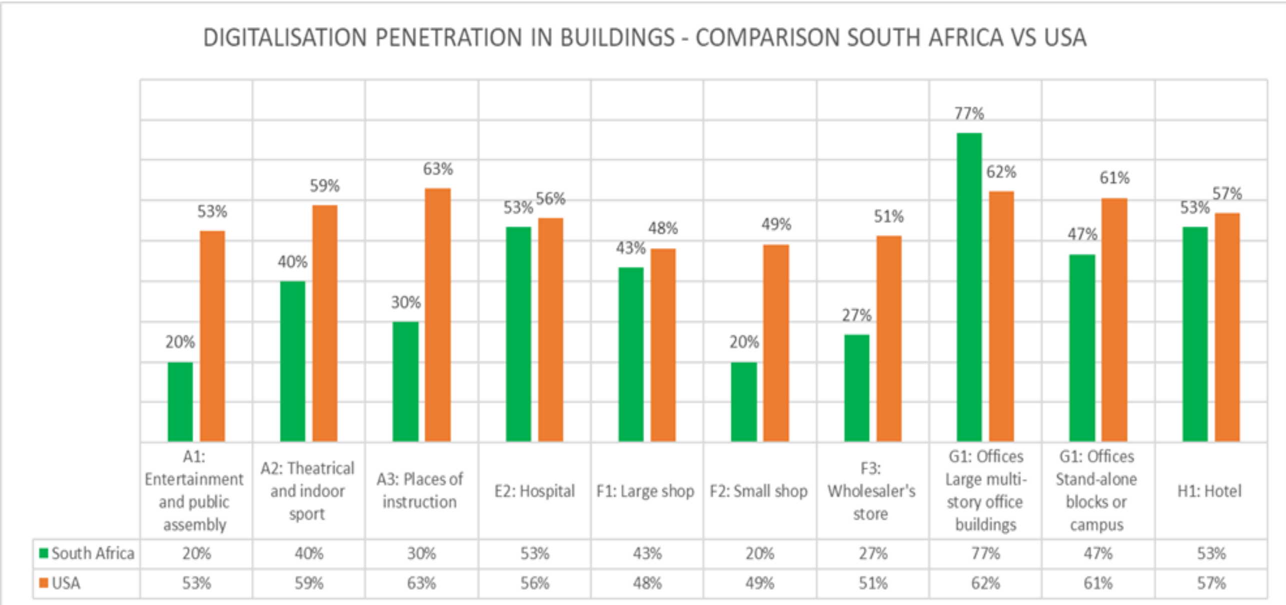


Figure 14. Digitalisation penetration in buildings - South Africa vs USA comparison

7. Conclusion

The analysis of the study results related to global and local buildings stages of digital penetration showed variety of differences in the compared categories. As indicated in the analysis above, this was due to the national regulations specific for the considered countries. However, one common trend emerged from the study, namely that the highest level of digital penetration is in the ***corporate business sector***, where the results of building digitalisation are assessed and utilized dynamically.

The high level of digitalisation of buildings in the reviewed countries is closely associated with the EPC. While the EPC process is recently introduced in South Africa, in other countries it is a normal business practice applied and regulated very intensively by the respective governments. Undisputable, EPC is an important catalyst for digitalisation, since it is influencing selling and renting property/ building prices and on the first place the operational cost of the buildings. In addition, the first round of issuing of the EPCs in South Africa will provide **baseline and benchmark** for the state of efficient energy consumption in the buildings and all energy sources in use. The information gathered could initiate **appropriate actions** from the Government to develop the relevant policies and incentive mechanisms for the optimization and acceleration of the digitalisation process of the buildings.

The COVID-19 pandemic imposed new requirements for safe, healthy and energy efficient operation of the buildings. Buildings in the post-pandemic world will be associated with **new technologies allowing connectivity** of people and equipment on a very high level of safety.

Considering the challenges which the South African electricity supply industry is experiencing at present, it is clear that properly digitalised /managed buildings could **mitigate** the above challenges, while providing additional and sustainable self-generating capacities. This can be achieved by employing **energy efficient and recovery technologies with the involvement of sustainable energy sources** in the commercial and residential buildings environments. Buildings need to be digitalised to provide better **flexibility, improved health working conditions, as well as increased adaptivity** for everchanging local and global disruptive events.

For South African conditions the following factors will drive and accelerate the digitalisation process of the buildings:

- The urgency of improving and normalizing the **electricity supply** of the country while incorporating the buildings energy sources, storage, recovery facilities and efficient systems.

- **Post-COVID-19 technology developments** which revealed the healthy and operational benefits of computerisation, remote working and communication, data-driven decisions, and much more.
- Mitigation of secondary COVID-19 impacts on the South African economy, while **creating new "green" jobs** especially for the **most affected vulnerable** population groups (women, youth and people with disabilities).
- Government's goal to reduce greenhouse gas emissions to **net-zero by 2050**.
- The **implementation of the Digitalisation Strategy** of the Government [21].
- And finally, is the **acceptance** that the buildings digital transformation is all about **modernising the business process with new technology and operational models** to achieve results otherwise not attainable by business as usual.

8. Recommendations

The study findings and conclusion backed by the analysis of the relevant buildings overseas, pointed out the crucial role South African buildings could play in improving the energy supply capacity of the country in a "green" and sustainable manner. The possible actions by the relevant actors in this domain could be summarised as:

ESKOM

- Establishing new programs like the former ESKOM's DSM: one for proposed ESKOM's Generation Division to utilise the alternative and co-generating facilities of the buildings and another one for ESKOM's proposed Distribution Division to benefit from the energy efficiency and alternative technologies while reducing the maximum and base loads of the national grid.

GOVERNMENT / DMRE

- Extending the existing Municipal EEDSM program of the DMRE to municipal and other buildings by involving dedicated digitalisation initiatives in municipal buildings as a starting point.
- DMRE and other relevant government departments to develop training programs in order to boost the socio-economic benefits of the building digitalisation process.
- Government to develop incentives for building owners / occupants involved and demonstrated proven success in the digitalisation of their buildings.

ELECTRICITY SUPPLIERS (ESKOM, MUNICIPALITIES AND OTHERS)

- Implementation of a compulsory digitalized monitoring and evaluation (M&E) (including real-time energy billing) to optimise the energy consumption, evaluate and sustain the savings (both energy and

CO_2) and ensure transparent and fair energy billing and charges.

SANEDI

- To assume a leading role in all government departments dealing with energy savings, related carbon emissions, environmental preservation and establish programs for their mitigation by developing comprehensive building digitalisation initiatives.
- To explore international organizations' involvement in supporting the local building digitalisation process.
- To spearhead a process based on the EPC results, while identifying buildings with high energy consumption and provide avenues and support to reduce the building energy consumption through relevant interventions.

RESEARCH / INNOVATION SUPPORTING ORGANIZATIONS

- Universities and other research and training /skills development organizations to be engaged and encouraged to develop and execute R&D for new technologies (including indigenous ones) backed with advanced training programs for the needs of expansion of the digitalisation to ALL South African buildings.

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Appendix I : Data Acquisition Questionnaire

Project Data Acquisition Questionnaire

State of Digital Transformation with specific focus on the energy efficiency potential on energy demand in the Buildings Sector:

Introduction :

The purpose of the questionnaire is to gauge the level of digital penetration (connected and controllable) within the facility. The questionnaire will assess the level of penetration with each question having a scoring weight of 0-5 depending on the question. The total scoring ranges indicate penetration levels as follows:

Between 0 and 5: Building has minimal digital penetration

Between 5 and 10: Building has some digital penetration

Between 10 and 15: Building has average digital penetration

Between 15 and 23: Building digital penetration above average

Greater than 23: Building has matured digital penetration

Presence of connected appliances/equipment	Within the building?	Score
HVAC, water heating or commercial refrigeration systems on digital system/platform	Yes (1)/No (0)	
Lighting systems on digital system/platform	Yes (1)/No (0)	
Building envelops, window/blind control and daylight harvesting on digital system/platform	Yes (1)/No (0)	
Smart Meters on digital system/platform	Yes (1)/No (0)	
Other systems on digital system/platform (Specify)	Yes (1)/No (0) Ans:	
Bonus point*: Alternative-generation (e.g Solar, Diesel, Gas, Wind) connected to monitoring infrastructure/digital platform	Yes (1)/No (0)	

Connected devices and system features	Detailed description	Score
Digital connectivity and communication	No connectivity (digital device operating independently)	1
	One-way local communication, restricted within the physical building	2
	One-way communication unrestricted within the physical building (e.g., accessible for grid operations)	3
	Two-ways communication with devices, equipment, and appliances within the building	4
	Two-ways communication with devices, equipment, and appliances within the building (and the grid)	5
Monitoring and reporting capabilities	Only monitor and report on the bulk energy consumption or generation in the building on a monthly interval	1
	Only monitor and report on the bulk energy consumption or generation in the building on a weekly/daily interval	2
	Only monitor and report on energy consumption or generation per technology / per floor / per tenant /per building section on a weekly/daily interval	3
	Monitor and reports on energy consumption or generation per technology / per floor / per tenant / per building section and relevant energy drivers (occupancy, business intensity, temperature etc.) on a weekly/daily interval	4
	Monitor and reports on energy consumption or generation per technology / per floor / per tenant / per building section, relevant energy drivers (occupancy, business intensity, temperature etc.) and predict future consumption based on historic data records (consumption and drivers), or external data sources (weather predictions) on a weekly/daily interval	5
Control Capabilities	Control decisions done manually based on insight provided by historical data collected by the monitoring and reporting system, in real-time or preprogramed by the building energy manger	1

	Control decisions made manually based on suggested actions presented by the monitoring and reporting system analytics, in real-time or preprogramed by the building energy manger	2
	Control decisions made automatically based on optimized techniques chosen among multiple strategies, balancing efficiency with flexibility and occupant comfort on a device-by-device/ technology-by-technology basis	3
	Control decisions made automatically based on optimized techniques chosen among multiple strategies, balancing efficiency with flexibility and occupant comfort considering interactions between interconnected devices. Having the ability to exchange data and control signals effectively and securely among connected devices / equipment (including renewable generation if applicable) / appliances and control systems	4
	Control decisions made automatically based on optimized techniques chosen among multiple strategies, balancing efficiency with flexibility and occupant comfort considering interactions between interconnected devices, coordinating, and executing complex adaptive control strategies based on changing conditions over multiple timescales	5
Inter-operability	No data exchange between connected devices possible (infrastructure and compatibility)	1
	Data exchange between connected devices possible but not implemented	2
	Data exchange between connected devices of the same type implemented for active energy management control within the building	3
	Data exchange between connected devices of different type implemented for active energy management control within the building	4
	Data exchange between connected devices of different type implemented for active energy management control within and outside the building (grid)	5
Data management and security	No Historical data is stored	0
	Historical data stored onsite without password protection and onsite control without data encryption	1
	Historical data stored onsite with password protection and onsite control without data encryption	2
	Historical data stored onsite, onsite control, password protection with data encryption.	3
	Historical data stored onsite and accessible offsite (offsite back up), remote appliance control, password protection and encryption.	4
	Historical data stored onsite and accessible off-site, remote appliance control, two-factor authentication password protection and encryption.	5
General	If the building isn't digitalized to the level your satisfaction, are the plans to digitalise the building soon? Ans:	N/A

	Any questions to the surveyors that you would like to ask with regards to digitalisation? Ans:	N/A
Total score / 30		

Appendix II: Building classes included in the study

Clusters Classification of Building occupancy and Building Description in accordance with SANS 10400-XA:2011	Building State of Digital Transformation (total score out of 30 – Presence of alternative generation section digitalized systems a bonus)					
	Digital technologies	Digital connectivity and communication	Monitoring and reporting capabilities	Digital devices / Equipment Inter-operability	Control Capabilities	Data management and security
A1: Entertainment and public assembly Occupancy where persons gather to eat, drink, dance or participate in other recreation						
A2: Theatrical and indoor sport Occupancy where persons gather for the viewing of theatrical, operatic, orchestral, choral, cinematographically or sport performances						
A3: Places of instruction Occupancy where school children, students or other persons assemble for the purpose of tuition or learning						
F1: Large shop Occupancy where merchandise is displayed and offered for sale to the public and the floor area exceeds 250 m²						
F2: Small shop Occupancy where merchandise is displayed and offered for sale to the public and the floor area does not exceed 250 m²						
F3: Wholesaler's store Occupancy where goods are displayed and stored and where only a limited selected group of persons is present at any one time						
G1: Offices Large multi-story office buildings, banks, consulting rooms and similar uses with lifts and energy consuming services that operate on a typical day-time occupancy.						
G1: Offices Stand-alone blocks or campus (or both) of buildings that form an office park but operate separately						
H1: Hotel Occupancy where persons rent furnished rooms, not being dwelling units						

Appendix III: Building classes excluded in the study

A4: Worship Occupancy where persons assemble for the purpose of worshipping
E3: Other institutional (residential) Occupancy where groups of people who either are not fully fit, or who are restricted in their movements or their ability to make decisions, reside and are cared for
H2: Dormitory Occupancy where groups of people are accommodated in one room
H3: Domestic residence Occupancy consisting of two or more dwelling units on a single site.
H4: Dwelling house Occupancy consisting of a dwelling unit on its own site, including a garage and other domestic outbuilding, if any

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