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Uganda national green data centre strategy and guidelines

THE REPUBLIC OF UGANDA
MINISTRY OF ICT & NATIONAL GUIDANCE

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Please consider the environment before printing this report.

Foreword

The **National Green Data Centre Strategy for Uganda** marks a critical step forward in our commitment to sustainable development and digital transformation. As data becomes the cornerstone of modern economies, ensuring that its management aligns with environmental sustainability is imperative. This strategy not only positions Uganda as a leader in green ICT initiatives within the region but also underscores our dedication to achieving the goals set out in the Third National Development Plan (NDPIII) and Vision 2040 of Uganda.

The strategy recognizes the vital role of energy-efficient and environmentally friendly data centres in supporting key sectors such as education, health, and agriculture while contributing to the reduction of Uganda's carbon footprint. It provides a roadmap for adopting best practices in green ICT infrastructure, fostering innovation, and enabling resilient digital services that cater to all Ugandans.

Our national goals demand a holistic approach to ICT development – one that balances technological advancement with ecological responsibility. By leveraging renewable energy sources, optimizing operational efficiencies, and promoting green investments, this strategy lays the foundation for a future where Uganda's digital growth is synonymous with sustainability.

I call upon all stakeholders – government institutions, private sector entities, academia, and development partners – to join hands in implementing this strategy. Together, we can create a robust, eco-friendly digital ecosystem that meets the needs of today while preserving resources for future generations. Let us embrace this opportunity to lead in the era of green innovation and achieve a truly sustainable Digital Uganda Vision.

Hon. Dr. Chris Baryomunsi
Minister of ICT and National Guidance

Foreword

It is my pleasure to present this report under the project 'Technical Assistance and Training to Uganda on National ICT Development Strategy', a collaboration between the Government of Uganda and the International Telecommunication Union (ITU), supported by the Global Development and South-South Cooperation Fund (GDSSCF) and ITU's ICT Development Fund (ICT-DF).

Through carefully co-crafted interventions in support of the country's vision to transform Uganda into a digitally enabled society that is innovative, productive and competitive, the project has applied a three-pronged approach focusing on the development of policy recommendations, enabling capacity development, and the implementation of pilot projects.

In recent years, Uganda has witnessed tremendous growth in its digital economy, reflecting broader trends across the African continent and globally. The increased access to digital technologies, new opportunities that connectivity has brought, and the surge in digital services are fueling rapid advancements on how citizens engage with one another and with vital Government services. These developments also bring new challenges, requiring policymakers and regulators to rethink strategically and build enabling policy and regulatory frameworks that are future-ready and adaptable to this ever-changing landscape. Moreover, digital skills remain an essential need for citizens to meaningfully participate in the digital space and for professionals to fully leverage the potential of digital technologies in addressing socio-economic challenges. This has been a critical aspect of the implementation of the policy interventions within this project.

This project, co-created and initiated in support of Uganda's ambitious digital transformation journey, stands as an example of how focused and meaningful partnerships can lead to impactful change. We have witnessed the results of the policy interventions and the impact of the significant capacity development in the country. I believe the efforts will continue to impact Uganda's transformation for years to come.

I encourage ITU's Member States across the African continent and globally as well as development partners to join forces and invest in digital transformation for social and economic growth. The Telecommunication Development Bureau stands ready to continue supporting countries on their digital transformation journeys with impactful project implementation and partnerships which are essential for achieving universal and meaningful connectivity and digital transformation for all.

Dr Cosmas Luckyson Zavazava
Director of the Telecommunication Development Bureau
International Telecommunication Union

Foreword

The **National Green Data Centre Strategy for Uganda** is the culmination of collective efforts and shared vision. It reflects our determination to balance Uganda's digital transformation with environmental sustainability, ensuring that technological advancements contribute to the global fight against climate change.

I extend my sincere gratitude to the International Telecommunication Union (ITU) and the Global Development and South-South Cooperation Fund (GDSSCF) from the Peoples Republic of China for their unwavering support in providing the technical expertise and financial resources essential to development of this strategy. Their partnership continues to serve as a cornerstone of Uganda's progress in digital transformation.

A special thanks goes to the technical team at the Ministry of ICT and National Guidance, whose dedication and expertise were pivotal in crafting this strategy. Their work in engaging stakeholders, analysing complex issues, and integrating sustainable practices into the framework was invaluable.

I am equally grateful to our partners from the private sector, academia, and civil society for their insights and collaborative spirit. Their input enriched the strategy, making it both comprehensive and forward-looking.

As we transition into the implementation phase, I urge all stakeholders to remain committed to the principles outlined in this strategy. Together, we can establish a resilient and sustainable ICT ecosystem that serves as a model for the region. Let us leverage this strategy to achieve a greener, more connected future for Uganda.

Dr. Amina Zawedde (PhD)
Permanent Secretary
Ministry of ICT and National Guidance
Government of Uganda

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Executive summary

Uganda stands at a crucial milestone in its digital transformation, seeking to pave the way for a more sustainable digitalisation across all sectors. The growing needs for digital services, combined with existing energy and environmental barriers, require transformative, innovative and structured ways to ensure the sustainability and competitiveness of the information and communication technologies (ICT) sector. This report presents an ambitious yet pragmatic roadmap for developing green data centres in Uganda, while taking into account national and international commitments and agreements, such as the Paris Agreement and the Sustainable Development Goals (SDGs). The national strategy for green data centres is based on pillars that enable the transformation of the digital landscape with minimal impact on the environment: modernizing infrastructure, optimizing energy efficiency and renewable energies, and strengthening skills and encouraging innovation.

Infrastructure Modernisation and Energy Efficiency Optimisation

Uganda must modernise its existing infrastructure for optimal energy performance. This can be achieved by reducing the power usage effectiveness (PUE)[2] to a competitive level of 1.4 to 1.6 by 2030, in line with international best practice. There will be a need to focus on advanced technologies such as adiabatic cooling systems, hybrid microgrid, and artificial intelligence (AI) for reduced consumption of energy and the cost of operations. It will also be important to focus on efficient air and thermal flow management through hot and cold aisle containment to reduce energy losses.

In addition to energy efficiency, data centre optimization can also be approached from the angle of connectivity; indeed, data centres siting close to the national backbone infrastructure can provide low-latency, high-bandwidth connectivity, which is essential for seamless operations.

Renewable Energies

Over 90 per cent of Uganda's energy comes from water (hydroelectricity), giving it the advantage of aligning its data centres with clean energy. Alternative sources, such as solar power, must accompany and support this process in order to withstand the impact of changes in climate such as drought (climate risk). Similarly, switching to alternative fuels, such as hydrotreated vegetable oil (HVO), would help reduce emissions from diesel generators. The aim is for photovoltaic panels, in addition to power purchase agreements, to provide between 5 per cent and 10 per cent of energy needs, in order to achieve 100 per cent renewable energy to power data centres by 2035., in line with the practices of other countries such as Kenya, and South Africa.

[2] PUE: Power usage effectiveness is a metric used to measure the energy efficiency of data centres, calculated by dividing the total energy consumption of the data centre by the energy used solely for IT equipment. The closer the PUE is to 1, the less energy is wasted on cooling, lighting, or other non-IT infrastructure.

Building competence and fostering innovation

In terms of sustainability for the ICT sector, local human skill development is crucial. Some 70 per cent of technicians are targeted to be fully trained in accordance with international standards by the year 2028, incorporating sustainable technologies as well. The most important in mobilising investments, enhancing local innovations, and facilitating technologies by incorporating leading edge solutions, such as those using Artificial Intelligence (AI) into energy management, and hybrid microgrids through public-private partnerships.

Why is this strategy important?

The surge in demand for digital infrastructure opens Uganda up to several critical challenges:

- **Environmental concerns**: Data centres remain energy-intensive facilities that contribute significantly to greenhouse gas emissions, hence the need to migrate to low-carbon infrastructure in order to meet climate commitments.
- **Regional competition**: While countries such as Kenya and South Africa have made considerable efforts to attract innovative technologies, Uganda has the opportunity to become a leader. By embracing clean, innovative technologies, Uganda will be able to leapfrog its competitors, establish itself as the market leader and set an example for green digital technologies in East Africa.
- **Socio-economic concerns:** The digital transition offers a unique opportunity to integrate communities by promoting green jobs and equitable economic benefits. This strategic approach will enable Uganda to reduce its carbon footprint, improve its economic competitiveness and play a central role in Africa's sustainable digital development.

How do we achieve this strategy?

Addressing transition to green data centres requires a well-defined roadmap and subsequent implementation, including:

1. Launch pilot projects:
   - Establish test centres for advanced technologies in Raxio facilities and those run by NITA-U, using, modern cooling systems, AI for energy optimization, and e-waste management solutions.
   - These projects could expect a 10 to 15 per cent[3] reduction in operational costs through decreased energy inefficiencies.
2. Establish an enabling regulatory and incentive framework:
   - Set national standards for data centres, including PUE targets and guidelines for the integration of renewable energy.
   - Provide fiscal and financial incentives such as tax reductions for investments in energy-efficient equipment or subsidies covering up to 30 per cent of initial costs[4].

[3] APL Data Center feedback on data centre and IT room refurbishment and optimization projects.
[4] Inspired by France's CEE program and Kenya's renewable energy incentive scheme.

3 Develop strategic partnerships:

- Work with international institutions such as the World Bank, African Development Bank or the Green Climate Fund, among others, to secure financing and expertise.
- Collaborate with local universities to train technicians and promote applied research.

4 Monitor and evaluate progress:

- Use interactive dashboards to track real-time key performance indicators, such as PUE, share of renewable energy, and CO_2 emissions avoided.
- Conduct annual audits for compliance with international standards, changing strategies based on outcomes.

Figure 1: Roadmap for sustainable data centres in Uganda

Source: ITU

The national strategy for green data centres offers Uganda the means to address environmental concerns while enhancing its economic and technological competitiveness. Thus, marrying innovation, inclusion of the local population, and sustainability, will make the country a model for sustainable digital transition in the region. To be successful, the approach needs all stakeholders involved, including government, private sectors, international partners, and local communities.

1 Introduction

Uganda stands at the watershed moment of transition with a rapid uptake of applications and ICT usage. This wave of change is witnessing a rapid growth in the demand for digital infrastructure, especially data storage, processing, and management. The data centre is the engine room of this transition providing critical enabling infrastructure for the public and private sectors as they transition towards the digital economy. However, with rapid growth, come significant challenges, especially concerning energy and environment friendly operational frameworks.

This report synthesizes the process for developing a national strategy and implementation framework for green data centres in Uganda. It covers an assessment of the analysis, recommendations, and strategic orientations produced throughout the project and provides key findings and recommendations.

This report does not include most of the technical and methodological aspects covered in the detailed documents produced during the course of the project. Furthermore, the outputs–such as the gap analysis, benchmarking report, and standards and guidelines for green data centres (available in the annexes)–provide detailed information on the topics addressed. All references throughout the report explicitly mention these documents. Readers who wish to explore the topics further or are interested in technical details are encouraged to consult these companion documents provided in the annexes.

This report sets out the strategy, analysis, methods, and recommendations and is intended for policy-makers, operators, investors, and other stakeholders, providing an opportunity to contribute to enabling the sustainable digital transition in Uganda.

Figure 2: Framework for developing a green data centre strategy

Source: ITU

Figure 2 outlines the framework for developing a green data centre strategy. This framework emphasizes the involvement of all stakeholders, including governments, private sectors, international partners, and local communities, to ensure a sustainable digital transition in Uganda.

2 Data centres in Uganda

In Uganda, data centres are a critical element of the nation's digital transformation, as they support the growing needs for data storage, processing, and management. It is essential to comprehend energy usage, sustainability practices, and infrastructural conditions as they stand today.

Indeed, having a solid grasp of the nation's digital infrastructure is essential to creating a strategy that works. It also provides a chance to learn about the reality faced by the various stakeholders, gather their perspectives, and understand their anticipated needs, as these stakeholders will be responsible for implementing this plan. Because of this, seven of local actors from the institutional and commercial sectors were interviewed and consulted.

The situational and gap analysis contains a detailed description of the findings, with the key points shared in this chapter. The detailed information that led to the results of the analysis can be found in Annex 1 below.

2.1 Current state of data centres in Uganda

Data centres are at the heart of Uganda's digital transition. They are the mainstay of government entities, the private sector and end-users in terms of data management. However, the development of data centres is being slowed down by aging infrastructures and a legislative framework that focuses very little on data centres. The aim of the following chapter is to provide an overview of the current state of data centres in Uganda. For the full analysis, refer to Annex 1.

2.1.1 Infrastructure and key stakeholders

Uganda is characterized by a diverse array of data centre infrastructure with varying levels of capacity, performance, and modernity. The following summary of the data centre infrastructure situation in Uganda is based on interviews conducted with various key stakeholders.

- **NITA-U (National Information Technology Authority-Uganda):** The national body in charge of overseeing information and communication technology (ICT) in Uganda. NITA-U oversees and manages public data centres, which are essential for housing government data. However, the technical infrastructures that are related to them (cooling systems, electrical systems, etc.) are aging and exhibit suboptimal performance levels with PUEs greater than 2.5. These centres, which currently have over 300 applications, will eventually reach their operational limit, which will hinder their possible future role[5].
- **Raxio Uganda**: The inaugural Tier III-certified data centre, Raxio is a carrier-neutral hosting service featuring a contemporary, highly resilient infrastructure. The operator, located in Kampala, provides interconnection and colocation services. Raxio, featuring a capacity of 400 racks and an installed capacity of 1.5 MW, is distinguished by its energy efficiency, exhibiting a PUE of 1.6 to 1.8, thereby solidifying its position within the regional digital ecosystem[1].
- **MTN Uganda**: A prominent telecommunications provider in Uganda, MTN utilizes its data centres for both its own services and those of external clients, particularly in the telecommunications and cloud industries. The data centres possess an old infrastructure with an energy performance level of approximately 2.5, indicating subpar energy efficiency[1].

[5] Annex 1: Situational and Gap Analysis Report, sections 2.1.1 and 2.1.2.

- **UTEL (Uganda Telecom):** A historic telecommunications provider, UTEL employs its centres for internal services and telecom solutions. However, outdated infrastructure and energy inefficiency limit their influence in the ICT ecosystem[1].

Table 1: Key data centre stakeholders in Uganda and their characteristics

Stakeholders	Amount of DC	Amount of rack	PUE
NITA-U	2	~300	>2.5
Raxio Uganda	1	400	1.6-1.8
MTN Uganda	6	_	>2.5

This list represents the identified major Ugandan stakeholders' data centres. It is, of course, not exhaustive. Other smaller data centres or server rooms likely exist within other ministries or private enterprises such as banks.

Although the data centres in Uganda offer a diversified landscape, they are dominated by persistent public infrastructure and innovative private initiatives such as Raxio. Despite ongoing modernization projects, current leadership capabilities are still insufficient to meet the growing demand for digital services[1].

[1] Annex 1: Situational and Gap Analysis Report, section 2.1.3.

2.1.2 Regulatory framework

Several public stakeholders have shaped Uganda's regulatory framework, which attempts to organize data centres' sustainable growth. However, there are significant gaps in the framework, which make it less effective. This section provides an overview and synopsis of the regulatory framework governing data centres in Uganda. For a comprehensive overview, please consult the Annex 1 "Situational and Gap Analysis Report"

Key stakeholders and their roles

- **National Environment Management Authority (NEMA**): This agency oversees the environmental compliance of infrastructures, especially data centres. Nonetheless, the lack of sector specific norms and standards sometimes constrains its impact. Enhanced collaboration with other institutions may amplify its impact[6].
- **Uganda Communications Commission (UCC):** The UCC is essential in regulating telecommunications facilities. Nevertheless, no legislation or guidelines specifically pertaining to data centres have been established[2].
- **Ministry of Energy:** Uganda's dedication to a sustainable future is manifested through this Ministry of Energy's instrumental role in the promotion of renewable energy sources. Nevertheless, the impact of these energy sources is restricted by the lack of dedicated strategies to integrate them into data centre infrastructures[2].

[6] Annex 1: Situational and Gap Analysis Report, section 2.2.1.

Key policies and their constraints

The present policy framework in Uganda exhibits that a process has been initiated by a variety of entities to enhance the country's dedication to sustainable development. However, this process is still insufficient in terms of data centre specific guidelines. Each policy offers opportunities, but it also has deficits that must be addressed to ensure that development is equitable:

- **National Environment Act:** This law establishes the groundwork for environmental management in the nation; however, it does not provide explicit guidelines for energy efficiency or infrastructure that is appropriate for data centres[2].
- **Renewable Energy Policy**: While it underscores the significance of renewable energy, this policy provides no explicit incentives for data centres to implement these solutions. The absence of subsidies or fiscal mechanisms diminishes investment prospects in contemporary energy infrastructure[2].
- **Waste Management Regulation**: While intended for the oversight of electronic trash, its implementation is sporadic and insufficient. Existing policies inadequately address the increasing waste produced by contemporary data centres, hence diminishing their efficacy[2].

Coordination between stakeholders

The lack of synergy between public institutions is a barrier to the development of green data centres in Uganda. Each agency acts on a specific perimeter, which tends to generate gaps in the creation and implementation of certain policies.

The limited interaction between key stakeholders such as NEMA, UCC and the Ministry of Energy results in a lack of development of a sustainable data centre sector. For example, the environmental standards set by NEMA are not always aligned with the technological objectives of the UCC, making it difficult to create infrastructures that are both modern and sustainable. This disconnect also slows down decision-making processes, particularly for projects requiring inter-institutional coordination.

In addition, the absence of a common framework discourages foreign investors, who prefer clear, harmonized regulatory environments.

> *Uganda's regulatory framework provides a solid starting point but does not fully address the needs of modern data centres, particularly in terms of sustainability and technological advancements. While various laws and policies touch on the sector, they lack clear, practical guidance to meet today's challenges.*
>
> *For example, the Environmental Act sets broad goals for sustainability but doesn't include actionable steps for improving energy efficiency or implementing green technologies suited to data centres. Similarly, the renewable energy policy emphasizes solar and hydroelectric power but offers no incentives to encourage their adoption by data centre operators.*
>
> *On top of these issues, agencies such as NEMA, UCC, and the Ministry of Energy often work independently, leading to fragmented responsibilities and inefficiencies. This lack of coordination hampers the development of a unified framework and discourages international investment, which relies on clear and cohesive regulatory systems.*

2.1.3 Energy and data centres and future outlook

The energy supply is a critical concern for data centres in Uganda, as it influences their efficiency, dependability, and sustainability. Despite the nation's wealth of renewable energy resources, such as hydropower, challenges related to energy infrastructure, including grid reliability and energy management systems, are impeding its complete realization.

Accessible resources

Uganda possesses an impressive energy portfolio, with over 90 per cent of its electricity derived from renewable sources, predominantly hydropower. This positions the country favourably for the development of green data centres. Nevertheless, these resources are still underutilized in the data centre sector, as numerous operators persist in depending on costly and environmentally harmful diesel generators to maintain commercial operations.

Energy challenges

Notwithstanding its advantages, Uganda's energy sector contends with obsolete infrastructure and recurrent power interruptions. These failures immediately impact data centre operations, heightening their need for energy-intensive backup systems. The electricity distribution system is experiencing substantial losses due to an ineffective transmission network, exacerbating the challenge of obtaining consistent and reliable energy.

Energy efficiency

Among the current data centre infrastructure, the Raxio Data Centre is distinguished by its contemporary focus on energy efficiency, boasting a competitive power usage effectiveness (PUE) of 1.6 to 1.8. In contrast, most other data centres possess PUE exceeding 2.5, signifying high energy use relative to international requirements.

Despite challenges such as outdated electricity transmission and distribution infrastructure, limited integration of renewables, and operational inefficiencies, Uganda has unique potential to transform its data centre sector into a model of sustainability. Targeted modernization of electricity transmission and distribution infrastructure, combined with greater integration of renewables, could significantly improve data centres' resilience and efficiency while reducing their carbon footprint.

Table 2: Data centres in Uganda

Aspect	Description	Strengths	Challenges
Infrastructure and key stakeholders	Diversity of public and private actors, each with specific roles:	– **Raxio Data Centre**: First Tier III data centre.	– UTEL and MTN rely on outdated infrastructure requiring investments for modernization.
		– **Raxio Data Centre**: A model of energy efficiency and modernity with 400 racks and a 1.5 MW capacity.	– NITA-U: Government infrastructure with critical services but saturated capacity, limiting expansion.
		– **NITA-U**: Offers critical services (disaster recovery, government hosting).	– Absence of international certifications (Tier III or IV) for MTN and other centres.
Energy performance (power usage effectiveness)	The PUE of Uganda data centres is generally above 2.0, reflecting energy inefficiency compared to international standards (Kenya, South Africa).	– **Raxio Data Centre**: Features modern energy management systems and a PUE of 1.6 to 1.8.	– Dependence on energy-intensive technologies in most centres (NITA-U, MTN, UTEL).
			– Lack of updates to align energy performance with international benchmarks.
Renewable energy	National electricity is 90% renewable, primarily from hydropower.	– Competitive advantage with a largely renewable energy mix.	– Limited utilization of this resource in the data centre sector, still reliant on diesel generators.
		– Growing interest in solar (e.g., Raxio), despite practical constraints such as limited space.	– Dependence on the national grid, which is prone to frequent interruptions.
Regulatory framework	The regulatory framework for data centres is still under development, with a favourable vision but few specific standards.	– Sustainability included in the National Development Plan III.	– Lack of defined standards for energy efficiency or renewable energy integration.
			– Institutional fragmentation between UCC, NEMA, and the Ministry of Energy.

3 Challenges of transition to green data centres

The transition to modern and advanced data centres in Uganda is essential for conforming the sector to worldwide standards and sustainability objectives. Nevertheless, various economic, institutional, and technical obstacles impede this progress. This chapter encapsulates these challenges, for a comprehensive perspective, please consult Annex 1.

Economic limitations

The substantial expenses related to infrastructure enhancement and the implementation of sustainable technologies continue to pose a significant obstacle. Upgrading cooling systems or installing solar panels necessitates an initial investment that frequently exceeds the financial capacity of local operators. This is exacerbated by the lack of financial incentives, such as grants or tax credits.

An example is the challenge incurred by centres operated by MTN, where insufficient access to affordable financing has postponed initiatives aimed at enhancing their energy efficiency. Due to a lack of public backing or tax incentives, local operators are prioritizing short term remedies, such as the augmented utilization of diesel generators, compromising sustainability.

Institutional obstacles

The Ugandan institutional framework is characterized by fragmentation and inadequate coordination among the primary institutions. NEMA and UCC adopt contrasting methodologies for environmental standards and energy objectives, leading to postponements in the execution of essential projects.

An example is the solar pilot project suggested by Raxio, which was postponed several months owing to disputes on installation requirements among the relevant agencies[6]. This low level of cooperation at the national level is also deterring foreign investors, who want more cohesive regulatory frameworks.

The National Development Plan III acknowledges the significance of sustainability; nevertheless, it does not provide explicit operational directives for incorporating these objectives within the data centre sector. This obstructs the establishment of a cohesive regulatory framework and hinders efficient coordination among essential agencies.

Technical constraints

Technical obstacles also hinder the modernization of data centres in Uganda. Obsolete equipment frequently elevates operational expenses and diminishes energy efficiency. Cooling methods employed in numerous facilities utilize 30 per cent more energy than contemporary alternatives.

The absence of suitable training programmes exacerbates the deficiency of local skills. This circumstance compels operators to rely on foreign specialists for the administration and upkeep of contemporary infrastructure, hence escalating expenses and hindering the swift adoption of innovative technology.

A significant example is the implementation of pilot projects for the integration of hybrid micro-grids or advanced energy management systems. These initiatives, while creative, frequently encounter obstacles associated with elevated costs and a shortage of trained personnel, hindering their implementation in the data centre sector.

Category	Main Obstacles	Examples
Economic	High costs, no subsidies or tax incentives	Energy projects delayed at MTN due to lack of affordable financing.
Institutional	Fragmentation between agencies, absence of a unified regulatory framework	Delays in Raxio solar projects due to conflicts between NEMA and the Ministry of Energy.
Technical	Obsolete equipment, lack of local skills	Energy inefficiency due to dated cooling systems; projects cancelled due to lack of expertise.

These obstacles illustrate the need for a concerted approach between public and private actors to overcome economic, institutional and technical challenges. Integrated solutions could transform the data centre industry into a model of sustainability and competitiveness for the region.

4 Lessons from benchmarking

A comparative analysis of Uganda's position regarding information technology infrastructure, sustainability practices, and data centre development also involve closely examining Uganda's positioning towards its neighbors and established global leaders in the global and regional competitive environment. The insights the comparative study of three countries provides opportunities for improving competitiveness while drawing out areas to be addressed to meet an acceptable set of regional and worldwide standards.

This chapter shares the main findings from the benchmarking analysis. For a comprehensive and thorough review, see Annex 2 "Benchmark Report".

4.1 Methodology

Goals and procedures

Benchmarking seeks to evaluate the performance of Ugandan data centres against those of prominent or adjacent nations by examining critical criteria such as energy efficiency (PUE), renewable energy integration, and sustainability certifications. These nations were selected for their notable advancements in:

- **Kenya**: A regional pioneer in digital infrastructure and renewable energy.
- **South Africa**: A paradigm for capacity, global certifications, and micro-networks.
- **France**: A global example in certifications, technological breakthroughs, and environmental legislation.

Data acquisition and examination

- **Review of literature**: A comprehensive study was conducted on institutional papers, case studies, and public datasets from the ITU, GSMA, and African Development Bank (AfDB). This research facilitated a precise delineation of the infrastructure and procedures of the countries under comparison.
- **Focused surveys**: Questionnaires were prepared and distributed to important stakeholders, including NITA-U, Raxio, and UCC. The surveys yielded quantitative and qualitative data regarding local capacities, technologies, and challenges.
- **Qualitative interviews**: In-depth interviews were performed with IT infrastructure specialists and operational managers in the benchmarking nations. The conversations yielded insights into governance processes and successful economic models.
- **Rigorous benchmarking**: The collected data were pooled and assessed based on specified measures, including the PUE, renewable energy integration, and certifications. This investigation discerned optimal practices relevant to Uganda.

4.2 Data centres compared: France, Kenya, South Africa

France

- **Standards and certifications**: France occupies a superb leadership position in global standards and certifications. France-based data centres such as ovhcloud adhere to stringent standards of EN 50600 and ISO 50001. These certifications attest to the higher efficiency of their energy use and an almost halving of the operational carbon footprint (Annex 2: Benchmark Report, section 5.3).

- **Sustainable strategies**: A worthy mention is repurposing heat for use in district heating systems.

Kenya

- **Technological advantages**: Kenya is distinguished by contemporary data centres such as icolo and East Africa Data Centre, which attain competitive Power Usage Effectiveness (PUE) ratings ranging from 1.4 to 1.6. This is accomplished via sophisticated cooling systems utilizing energy-efficient technology and the incorporation of geothermal energy, a plentiful resource in Kenya (Annex 2: Benchmark Report, section 3.3). This amalgamation guarantees energy dependability while diminishing operational expenses.
- **Supportive regulation**: The Kenyan regulatory system promotes green investment. Fiscal incentives, including reduced taxes on ecologically sustainable equipment, have facilitated the adoption of renewable energy in data infrastructure (Annex 2: Benchmark Report, section 3.4). These measures have drawn significant industry participants and bolstered Kenya's status as a regional leader.

South Africa

- **Capacity and connectivity**: South Africa is now poised in grandest terms to become an African hub with a network of 41 data centres. Firm of Teraco attracts investors with Tier III and IV certified infrastructures, ensuring much better reliability and security standards. This country is connected to many substantial international submarine cables, providing an incredible level of connectivity into the marketplace and extremely low latency for local customers (Annex 2: Benchmark Report, section 4.2).
- **Innovative technologies**: The hybridization of microgrids with solar energy and battery storage is one way to enhance energy resilience in the face of rolling blackouts (Annex 2: Benchmark Report, section 4.3).

4.3 Essential Insights and strategies in Uganda

Benchmarking practices after the study revealed key practices that can be adapted for Uganda as part of efforts to reposition the data centre sector while achieving sustainability and competitiveness goals.

- **Renewable energy integration**: Uganda has more than enough solar energy and water resources that it could use to fuel its data centres and significantly reduce their carbon footprints. Building on the exciting success in Kenya, with geothermal and solar in the mix, such an avenue in Uganda provides a great opportunity to build confidence in energy resilience and sharply cut operational costs (Annex 2: Benchmark Report, section 3.3).

Adherence to international standards such as Tier III/IV and ISO 50001 is paramount if data centres in Uganda are to achieve higher reliability, security, and energy efficiency. Such certification is widely applied by South Africa and France and attracts foreign direct investment while guaranteeing very high performance standards. These certifications would thus enhance confidence among regional and international economic stakeholders in Uganda.

- **Innovative technologies**: The hybrid microgrid comprising solar energy, battery storage, and smart energy management may provide a solution to the energy problem. In South Africa, this ensures continuous supply even when national grid fails. While in France, the immersed cooling systems are achieving greater energy efficiency and can be adapted to the infrastructure of Uganda so that cooling systems' energy consumption can be reduced.
- **Enhancing public-business partnerships**: Drawing from the Kenyan model, partnership between the government and the business sector facilitates investment attraction and

infrastructure modernization. These agreements may encompass tax incentives for private operators, collaborative funding programmes, or research activities aimed at creating solutions specific to the local market.

- **Training and skill enhancement**: A significant difficulty recognized in Uganda is the deficiency of skilled labour to operate modern technologies. The South African and French cases demonstrate that the creation of specialized training programmes, in collaboration with academic institutions and industry leaders, is crucial for bridging this gap and assuring the sustainability of contemporary infrastructure.

Benchmarking lessons from France, Kenya, and South Africa, have shown Uganda's great potential to institute modernization of its data centres with international best practices. To transform Uganda into a leading force for sustainable digital transformation in east Africa, the government must introduce renewable energy, adopt international standards, and encourage innovations in technologies)

Table 3: Comparison of key data centre metrics in France, Kenya, and South Africa

Criteria	France	Kenya	South Africa
Average PUE	< 1.2	1.4 - 1.6	1.8
Share of Renewable Energy	20%	90%	35%
Adopted Standards	ISO 50001, LEED	ISO 50001, LEED	Tier III and IV
Incentive Policies	Strong	Strong	Moderate

5 Strategic framework and **challenges** for green data centres

Uganda is at a decisive stage in its digital and environmental transition. To address the growing challenges of sustainable development and digital needs, the strategic framework presented here is a comprehensive and realistic vision for the development of green data centres and it aims to reconcile energy efficiency, environmental responsibility, and operational resilience. Inspired by successful models observed in France, Kenya, and South Africa, as well as Uganda's national priorities, the strategy is built on four key pillars, positioning the country as a model of innovation and sustainability. The transformation of data centres in Uganda to a more environmentally friendly infrastructure requires a strategy that will not only overcome major challenges such as aging infrastructure, inefficient energy management, and increased exposure to climate risk, but will also align digital transition ambitions and the growing needs of the digital economy in Uganda with international standards and best practice.

Compliance with national and international commitments

This green data centre strategy of Uganda fits squarely in the country development goals framework. In Vision 2040, sustainable digital transformation is acknowledged as one of the levers for economic transformation alongside modern green infrastructure[7]. In the Third National Development Plan (NDP III), environmentally sustainable infrastructure that would lead to a low-carbon economy has provided a rationale for the plan. Meanwhile, in line with the nationally determined contributions under the Paris Agreement, the intention is to reduce greenhouse gas emissions by 22 per cent by the year 2030, focusing on energy efficiency and renewable energy[8].

Digital sovereignty and sustainability as a strategic goal

Uganda is moving toward rapid digital transformation, and thus national data domination is very crucial. Equipping Uganda with green data centres is, hence, a remedy to that. These infrastructures signify an assertion, rather than one of formalities, of its digital independence and hence will go a long way in assuring that Uganda remains able to hold sensitive data by reducing its reliance on foreign infrastructure. These green data centres are more than mere technological instruments. They hold a larger goal: that of combining economic growth with respect for the environment. Through their sustainable nature, such infrastructure secures the digital transition, where such expansion takes place in unison with the local ecosystems (Green Data Centre Strategy Report, 2022; Smart Africa Initiative Report, 2021).

Responding to climate change

The environment offers challenges to information infrastructures within Uganda. Already in the country, floods, drought, and high temperatures threaten the operating state of data centres. More than the mere theoretical threats, there is an immediate practical response to be taken regarding them. This necessitates reflecting upon the construction of climate-resilient infrastructure in extreme weather, including better flood-resistant buildings or energy-efficient cooling systems. Hybrid microgrids utilizing solar power and battery storage are in place and slowly mediate the perennial power outages. Such measures promote business continuity with minimal disruption to data centres' environmental approaches.

7 Uganda Vision 2040
8 UNFCCC, nationally determined contributions, 2021

Responsible management of natural resources

Renewable energy is perceived to be a key resource in Uganda, with more than 90 per cent of energy produced from hydropower; this potential may have received inadequate appreciation in the data centre industry. Solar energy must be introduced as a counter-drought measure in urban and rural areas. Likewise, water use in supporting cooling systems should be decreased; this could be achieved using highly resource-efficient closed-loop technologies. Finally, the management of e-waste should also be improved with the establishment of local recycling streams focused on recycling activities in specific areas to mitigate environmental effects[9].

Improving efficiency for increased competitiveness

Energy presently contributes significatively on the operational costs of data centres in Uganda. This has major implications for their operating capacities because few options are available to mitigate it. Uganda is therefore faced with the responsibility of setting up energy-efficient data centres. Most of the existing sites have a power usage effectiveness (PUE) above 2.5 compared to international benchmark. Uganda ought to establish a PUE between 1.4 and 1.6 through an investment in advanced cooling systems, energy system automation, and optimization of consumption[10].

Developing local skills and fostering partnerships

In reality, Uganda is plagued by the issue of a shortage of qualified personnel capable of operating and maintaining the modern data centre and their predecessors, which have a high-efficiency approach. To counter this gap, working alliances for private partners outside of Uganda need to be established with local universities to develop tailored training curricula in renewable energy and in digital infrastructure management (Public-Private Partnership Report, World Bank, 2021). Public-private partnerships would equally result in a cost-sharing, knowledge-sharing, and acceleration capacity for the green data centres.

Positioning Uganda as a regional leader

It gives Uganda a very political outlook on leading the charge for green data centres. It could serve as a model for neighbouring countries while also bringing in foreign investments by being the champion of innovative solutions and sustainability. Such positioning reinforces Uganda's positioning and commitment in the digital and green transition of Africa.

5.1 Strategic pillars

5.1.1 Pillar 1: Reducing energy costs

Target: Reduce energy costs by 30 per cent by 2028

Energy costs figure prominently in operating costs, which are strongly linked to aging infrastructure that is highly dependent on diesel generators, but also to long-term energy costs. Uganda could benefit from upgrades to its energy systems, as demonstrated by examples such as ovhcloud in France, which has reduced costs by 35 per cent through cooling technologies and IoT (Benchmark Report, Section 3.2). The government could then share data centre upgrades

[9] Uganda Waste Management Regulation
[10] Uganda Energy Regulatory Authority

with the private sector, which could greatly benefit from this leverage by modernizing the antiquated infrastructure.

Key actions

- **Modernize cooling systems**: Containment technologies for hot/cold aisles effectively optimize airflow in the data centre and partially reduce energy consumption. Even more advanced, the liquid immersion cooling solution eliminates the need for cooling infrastructure entirely.
- **Track energy consumption with Internet of Things (IoT)**: Integration of IoT sensors would allow real-time monitoring of data centre energy consumption, IT equipment performance indicators and temperatures. The follow-up of the actions makes it possible to correct the uses and to plan the maintenance.
- **Integrating hybrid systems in the centres:** Replacing diesel generator alloys with hybrid battery/renewable energy systems ensures a stable electricity supply when the grid is interrupted.

Specific case

- **France:** ovhcloud reduced the cost of its energy requirements by 35 per cent thanks to its state-of-the-art cooling systems (Benchmark Report, Section 3.2) and the use of IoT (Benchmark Report, Section 3.2).
- **Kenya:** Liquid Intelligent Technologies data centres have achieved an UPS of 1.4 with significant operational cost savings (Kenya Data Centre Insights, Chapter 4).

5.1.2 Pillar 2: Integration of renewable energy

Target: 100 per cent renewable electricity use by 2035

With an electricity mix dominated with more than 90 per cent hydropower, Uganda is already well placed to acheive this goal. There is, however, a hydropower dependency risk in times of drought, which calls for the incorporation of solar and wind power sources. This approach is viable, as we draw lessons from the Kenya model based on solar power purchase agreements .

Key actions

- **Sustainable energy partnerships**: Develop long-term solar and wind power purchase agreements with local solar and wind energy producers to enable them to provide stable supply services at the best rates.
- **Installation of solar panels**: Install solar panels on all roofs of data centres needing solar coverage to fully meet up to 10 per cent of energy demand by 2035, in addition to power purchase agreements. Investigate flexible solar technologies appropriate for small sites.
- **Installation of storage systems**: Install energy storage systems for backing hydropower and solar to guarantee energy reliability when grid instability occurs.

Specific case

- **Kenya**: Solar power purchase agreements reduced operational costs by 25 per cent while cutting emissions.
- **South Africa**: Hybrid micro-grids have enhanced energy reliability with an associated reduction in carbon footprint.

5.1.3 Pillar 3: Transition to resilient and low-emission Infrastructure

Target: Reduce greenhouse gas emissions by 40 per cent by 2030 and carbon neutral by 2050

Reduction of emissions is consistent with commitments that Uganda made under the Paris Agreement and its nationally determined contributions. Implementing technology changes such as hybrid micrograms for new systems and carrying out infrastructure upgrades could greatly decrease the carbon hallmark while improving operational resilience.

Key actions

- **Invest in hybrid microgrid applications**: Construct stand-alone systems that combine solar, wind, and batteries to guarantee a reliable and consistent energy supply that will impact grid dependence for electricity, and diesel generator use.
- **Upgrade existing infrastructure**: Retrofits for data centres with technologies such as energy-efficient HVAV systems and tools for dynamic power allocation.
- **Develop and join carbon reduction projects**: Participation in local reforestation efforts, as well as investment in renewable energy projects that serve to offset residual emissions.

Specific case

- **South Africa**: Microgrids powered by renewable energy have helped to provide resilience to outages and brought down emissions.

5.1.4 Pillar 4: Promotion of innovation and skills development

Target: By the year 2028, at least 70 per cent of local technicians should be trained in green technologies.

Ensuring that local capacity is in place remains the single most important pillar to ensure a sustainable and autonomous digital infrastructure for Uganda. There is the Kenyan example where more than 500 technicians have been trained through public-private partnerships to signify what such initiatives can accomplish.

Key actions

- **Establish academic partnerships**: Collaborate with universities and technical institutes to create certification programmes in green data centre management. Include hands-on modules in renewable energy systems and IoT-based operations.
- **Support for uptake of qualifications**: Incentivize Data Centre Operators to take on internationally recognized system certifications, including (but are not limited) to (LEED) and (ISO 50001) through training cost subsidies or tax exemptions.
- **AI Integration**: Integrate AI systems using a pilot in energy management and optimal operational workflows.

Specific case

- **Kenya:** More than 500 technicians are trained in green technologies under public-private initiatives in the country (Smart Africa Alliance Report, Section 4.5).

The four strategic pillars: reducing energy costs, integration of renewable energy, transition to resilient and low-emission infrastructure and promotion of innovation and skills development elucidate a clear and ambitious route towards the transformation of Uganda's data centre industry. Uganda can establish itself as a regional leader for sustainable digital transformation by focusing on energy efficiency, renewables integration, infrastructure resilience, and skills development.

5.2 Strategic prioritization and governance framework

The establishment of green data centres in Uganda can no longer only focus on environmental goals but must start to embrace a real opportunity for the communities that can arise from this endeavour. There should be a continuing focus, even as priorities for strategic actions are being created and governance frameworks strengthened, on seizing opportunities that will provide advantages for local communities, such as job creation, the use of heat reuse, access to surplus electricity, etc., thus ensuring that Uganda's green data centre initiative contributes holistically to national development, sustainability, and more community welfare.

5.2.1 Key priorities and actionable solutions

Accomplishing energy availability and reliability is key to Uganda's green data centre ambitions. While there is a sufficient mix of renewables, grid interruptions and seasonal droughts hinder an uninterrupted energy supply. Diversifying the energy sources by marrying hydroelectricity and solar power with hybrid microgrids will guarantee data centre stability and sustainability. The surplus electricity generated through these systems can also be drawn to nearby communities for reliable energy to power homes and businesses and ultimately lead to community development.

Modernizing obsolete infrastructure is another priority. Existing data centres tend to consume significant amounts of energy, often due to their cooling systems. An upgrade in cooling technologies using adiabatic systems or the introduction of modular infrastructures would save energy. In addition to cutting down on operational costs, they provide another opportunity of sharing the waste heat with the surrounding one. For instance, the data centre generated heat can be applied to enabling heating, when needed, to public facilities, such as hospitals, schools, or greenhouses, thereby bringing value to the community.

Capacity building is central to entrenching the use of green technologies. The lack of skills impacts on the construction and functioning of modern, sustainable data centres. Collaboration with local universities and international experts can allow for the establishment of capacity building programmes and training curricula that will support the renewable energy sector and advanced data centre technologies, bridging the skills gap and promoting the creation of high-value jobs for the socio-economic development of communities.

Cost-cutting strategies are indispensable in this case, given Uganda's financial constraints. Investing in low-cost pilot projects under scenarios requiring demonstration-based schemes to capitalize on short-term gains, such as installation of rooftop solar panels, is easier to realize. Phase-based investments in hybrid microgrids and modular solutions can be extended over a longer time to lessen fiscal pressures. This also has an energy-efficiency advantage in itself, which will end up putting savings in a reduced energy bill, and better service reliability to the local communities.

5.2.2 Governance and collaborative approaches

A sound governance framework is fundamental to achieving the outlined objectives. Apart from raising awareness, a national committee on green data centres could aid in facilitating regular communication between government agencies, private operators, and international partners. Defining the functions of the stakeholders is equally important. For instance, these could include the Uganda Communications Commission (UCC) on environmental and digital standards, as well as the National Environment Management Authority (NEMA) to ensure compliance with this environment. In addition, the Ministry of Energy could then include renewable energy from the national grid and microgrids in powering data centres.

However, a strong emphasis must be laid on public-private partnerships. Uganda should encourage green private stakeholder investment and partnerships, such as developing green infrastructure. It will also need incentives such as tax holidays or grants to encourage the investment in green technologies. Such partnerships would provide innovative solutions such as repurposing waste heat or surplus from energy use to meet urgent needs in communities, such as district-wide heating projects or energy supply for underserved areas.

Collaboration among different stakeholders is another way to maximize impact. Collaborating with academic institutions comes with an opportunity to provide capacity-building in the process of developing the data centre thereby creating skilled workers who will understand how to manage sustainable infrastructure. On the other hand, the complementary skills and the investment will bring along technical assistance and funding through international organizations to inform Uganda's efforts to obtain tools and examples to learn from.

5.2.3 Monitoring and evaluation mechanisms

Important for accountability and progressive improvement, monitoring the extent of operations is crucial. With a national dashboard, it will be possible to provide real-time monitoring of performance indicators (such as integration of renewable energy into the national grid, power usage effectiveness (PUE), greenhouse gas reduction achieved, and the rate of technician training across regions. The system will also track community benefits, such as dissemination of surplus power and repurposing of waste heat.

Periodic audits of environmental and energy standards will ensure compliance. Evaluations might track the real community impacts of such projects: how many new jobs were created, how much waste heat was repurposed, and how much new electricity was provided to local areas. Annual stakeholder forums will provide an opportunity for sharing of existing progress, challenges being faced, and adjustments to the strategy to create maximum benefits for the communities.

5.2.4 Financial mechanisms for sustainability and community impact

Sustainable financing models will prioritize projects that benefit both the data centre sector and the population at large. Subsidies and fiscal incentives can promote investments in advanced technologies, such as solar panels and cooling systems, and acquiring funding will enable the Government of Uganda to scale its projects, and support other projects centred around communities.

Cost-sharing projects could be designed amongst operators, not only to lessen the financial burden but to create a wider pool of benefits, however small, for local communities. For example, solar farms co-financed by various operators could supply surplus energy to nearby villages while excess energy from data centres could support local public services with lower billing.

5.2.5 Aligning with national and community goals

Green data centres represent an excellent opportunity for Uganda to bring its digital transformation in line with wider national and community aspirations. Building green data centres that adopt renewable energy and low-carbon technologies will lower the carbon footprint of data centres and, at the same time, still foster economic growth. Community-based initiatives, including job creation, waste heat sharing, and surplus electricity distribution should allow countries in east Africa to build green data centres that will have a wider benefit beyond the industry itself and thus support their sustainable development goals.

Table 4: Strategic framework for sustainable data centre development: objectives, actions, and best practices

Aspect	Objectives	Priority Actions	Inspiring Examples
Alignment with Commitments	– Contribute to national objectives (Vision 2040, NDP III, nationally determined contributions under the Paris Agreement: 22% GHG reduction by 2030).	– Harmonize environmental and digital regulations.	– **Kenya**: Introduced fiscal incentives to encourage green infrastructure.
	– Meet international commitments (Paris Agreement, SDGs).	– Promote international certifications (ISO 50001, LEED).	– **France**: Applied EN 50600 standards for sustainable data centre management.
Pillar 1: Energy efficiency	– Reduce energy costs by 30% by 2028.	– Modernize cooling systems (hot/cold aisle containment, adiabatic cooling).	– **ovhcloud (France)**: Reduced operational costs by 40% with advanced cooling.
	– Achieve a competitive PUE (1.4–1.6) by 2030.	– Integrate IoT sensors and AI to monitor and optimize energy consumption.	– **Teraco (South Africa)**: Used IoT sensors to reduce energy costs by 30%.
Pillar 2: Renewable energy	– 100% renewable electricity by 2035.	– Sign power purchase agreements with hydroelectric producers.	– **Kenya**: Solar power purchase agreements cover 15% of public needs, reducing operating costs by 25%.

Table 4: Strategic framework for sustainable data centre development: objectives, actions, and best practices (continued)

Aspect	Objectives	Priority Actions	Inspiring Examples
	– Reduce emissions from diesel generators by using HVO by 2030.	– Install solar panels	– **South Africa**: Converted diesel generators to HVO, reducing emissions by 40%.
Pillar 3: Low-carbon and resilience	– Reduce GHG emissions by 40% by 2030.	– Build autonomous hybrid microgrids.	– **France**: ovhcloud uses microgrids to enhance resilience and reduce its carbon footprint.
	– Achieve carbon neutrality by 2050.	– Use thermal materials to protect structures from heatwaves and floods.	– **South Africa**: Teraco modernized with autonomous hybrid systems.
Pillar 4: Innovation and skills	– Train 70% of local technicians by 2028.	– Develop specialized training programmes with local universities.	– **Kenya**: Trained 500 certified technicians to modernize digital infrastructure.
	– Certify 80% of data centres to international standards by 2030.	– Encourage pilot projects with AI-based solutions.	– **South Africa**: Teraco reduced energy costs by 25% using AI.
Governance recommendations	– Establish a National Green Data Centre Committee with public and private stakeholders.	– Create a national dashboard to monitor KPIs (PUE, renewables, GHG).	– **EU**: Interactive dashboards track sustainable infrastructure progress.
		– Conduct periodic audits to evaluate compliance with international standards.	– **Singapore**: Annual energy strategy adjustments based on collected data.
		– Offer subsidies and tax incentives for sustainable investments.	
		– Facilitate access to international financing (e.g., Green Climate Fund).	

6 Guidelines for implementation

Sustainable development is increasingly recognized as a crucial element of global progress, especially in energy-intensive sectors such as data centres. These infrastructures are very important for the phenomenon of digital transformation; however, their energy use and negative environmental footprint pose potential problems. Uganda, with its ambition of becoming a regional leader in digital infrastructure, must engage to align its data centres with international standards, all the while benefiting from its renewable energy potential.

In this chapter, very detailed guidelines for the design, construction, and sustainable operation of data centres are discussed. These recommendations adopt the life-cycle approach, hoping to achieve optimization in energy efficiency, reduced carbon footprints, and trajectory towards sustainability. They are adapted to Uganda's local realities and constructed with input from international best practices.

It will provide an operational and technical roadmap for decision-makers, operators, and investors towards building modern, efficient, and environmentally friendly infrastructure.

6.1 Green design standards

The opportunity for Uganda to develop green data centres is a wonderful chance to unite digital infrastructure with sustainability and economically and socially sustainable values. Below are detailed recommendations for implementation to provide very practical guidance.

6.1.1 Criteria for size and location

Optimal sizing

- **Modular design**: The modular design of the data centres will facilitate future extensions as demand for additional capacity increases. One suggestion is to start with one basic unit to meet immediate requirements and add new modules as the demand for either storage or processing arises. This reduces the initial outlay of cash and prevents overbuilding. Modular designs also allow for easier integration of future technology upgrades without requiring a full overhaul.
- **Needs forecasting**: Make use of more sophisticated predictive analytical tools, including AI-driven simulations, to determine data storage and processing needs in 5 and 10 years down the road. Sectoral trends (telecom and public services, for example) of growth should also inform these predictions in a way that optimizes sizing. The watchful analysis of forecast data will periodically match it with changes in demand.
- **Local adaptation**: Data centres should be designed in such a way that they meet the special needs of vital sectors, for example, for telecommunications may require wide-band, low-latency setup, for public services may need high security and redundancy of sensitive data, hence appropriate location selection.

Figure 3: Modular data centre design

Source: ITU

Strategic location selection

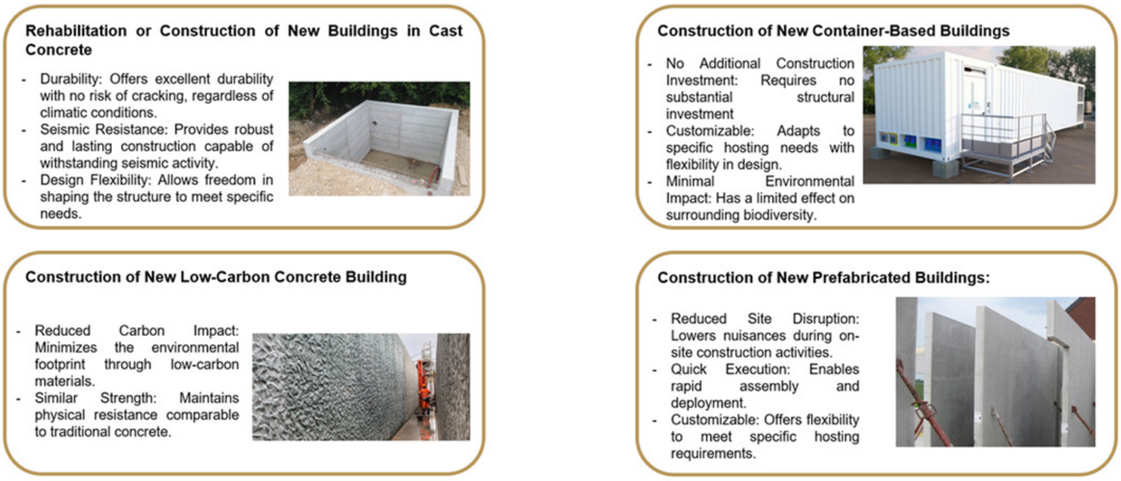
- **Proximity to renewable energy sources**: Establish data centres as close as possible to hydropower plants such as Karuma Dam or solar-drenched areas such as Karamoja. This guarantees stable and renewable energy access with minimal losses in transmission.
- **Connectivity hubs**: It is best to select a location close to national backbone infrastructure for low-latency, high-bandwidth connectivity that will benefit operations; indeed, being near to major urban centres where connectivity is good is also a great advantage.
- **Favourable climate**: Another crucial factor would be cool areas, for instance, the Western Highlands, where natural ambient temperatures would ease cooling. This causes a decrease in operational survival cost and a reduction in dependence on energy-hungry cooling systems.
- **Climate resilience**: Conduct thorough climate risk assessments to identify locations that are not vulnerable to floods, landslides, or other environmental hazards. Use GIS software that helps in delineating and defining safe, resilient landscapes.

6.1.2 Sustainable building design

Construction materials

- **Locally sourced, low-carbon materials**: The building materials must include compressed earth bricks, bamboo, recycled concrete, etc. In consideration of these, they are also the ones that will boost local industries and minimize transportation-related emissions and associated costs.
- **Reflective roofs**: The designed reflective roofs must be put in place to reflect the sunlight away and high-performance insulating materials put in place to keep the temperatures down in the buildings thereby confirming the limited use of the cooling systems.

Figure 4: Options for sustainable data centre construction



Source: ITU

Passive cooling techniques

- **Green facades and rooftop gardens**: Exterior walls will be thought to be planted with vegetation with roof gardens that naturally act as thermal insulators. This can also enhance biodiversity and mitigate the urban heat island effect.
- **Moisture-regulating materials** such as rammed earth are useful in providing natural temperature regulation thereby decreasing their potential active cooling systems need.

Energy recovery systems

- **Install equipment for ongoing heat recovery** from servers and other IT equipment for utilization in heating other nearby applications such as district heating and industrial process heating.

6.1.3 Technical equipment

Cooling systems

- **Adiabatic cooling**: These systems operate on the principle of evaporative cooling, whereby air is cooled through the evaporation of water. They can provide significant energy savings of around 90 per cent. Such systems work best in warm, dry climates.
- **Direct liquid cooling**: These cooling systems are connected directly to IT components- such as processors-and can obtain about 20 to 30 per cent energy savings compared to conventional air cooling systems.
- **Low global warming potential refrigerants**: This refrigerant can cut 90 per cent of greenhouse gas emissions compared to the traditional refrigerant.
- **Geothermal cooling**: Utilizing underground temperature to expel heat. For larger installations, boreholes or geothermal wells can be installed, allowing for reductions of energy costs reaching as high as 50 per cent.
- **Free cooling**: Providing free cooling schemes to make use of cool outdoor air for controlling the indoor temperature, especially well-suited for cooler regions such as the Western Highlands.

Electrical distribution systems

- **High-efficiency inverters**: Install inverters with energy conversion efficiency of up to 98 per cent to minimize power loss during power distribution.
- **Energy storage batteries**: Employ leading-edge battery technologies, such as lithium-ion batteries for renewable energy to allow the supply of uninterrupted power during outages on the grid or during lower generation yields.
- **Microgrids and cogeneration**: Development of microgrids will comprise solar, wind, and battery systems. The cogeneration process in which simultaneous production of electricity and heat may get efficiency up to 80 per cent.

Fire suppression systems

- **Inert gas systems**: Extinguish fires without leaving residues, ideal for sensitive IT environments.
- **Water mist systems**: Reduce water usage by 80 to 90 per cent, limiting damage to IT equipment.
- **Advanced detection**: Use smart sensors for early detection and rapid response.

6.1.4 IT room

Airflow optimization

- **Hot and cold aisle configurations**: Organize servers to separate hot and cold airflows. Use containment systems to isolate hot air, reducing cooling needs by up to 30 per cent.
- **Advanced airflow simulations**: Use computational fluid dynamics (CFD) tools to model airflow patterns for improved cooling efficiencies.

Figure 5: IT room containment

Source: ITU

IT equipment

- **Energy-efficient servers**: Use servers with energy-saving features such as sleep modes; this measure could significantly reduce energy consumption by 50 per cent or more.
- **High-density storage solutions**: Reduced energy use of up to 50 per cent over conventional hard drives.

- **Virtualization and workload consolidation** can optimize server usage, thus reducing hardware requirement by up to 50 per cent.

Workload management:

- Use orchestration tools to allocate resources based upon real-time demand, reducing the waste of resources.
- Data management, e.g. tiering or compression, could be utilized to achieve resource efficiency and reduced energy consumption.

6.2 Standards for eco-responsible construction

6.2.1 Site preparation

Environmental impact assessments

- **Perform comprehensive studies** to identify ecologically sensitive areas and mitigate biodiversity loss.

Soil and erosion management

- **Use techniques such as retaining walls** and vegetation planting to stabilize soil, especially in sloped areas.

6.2.2 Sustainable construction practices

Modular and prefabricated construction

- **Modular and prefabricated construction**: The use of modular and prefabrication construction methods will minimize waste, accelerate timelines, and cause minimal disruption to the environment:
    - This off-site assembly will reduce on-site construction activity and construction waste by nearly 80 per cent.
    - These are highly beneficial for remote areas, where conventional construction requires extensive logistics and creates a lot of waste.

Water and energy efficiency

- **Use temporary rainwater harvesting systems** on-site for construction to reduce reliance on municipal water supplies to spray down dirt/mud or mix cement.
- **Portable solar panels** would power the construction site equipment, office, and lights while ensuring that activities remain environmental-sensitive far from the grid.

6.2.3 Modernization of existing structures

Compliance with modern standards

- **Retrofitting underutilized urban buildings into data centres** can save resources and reduce construction emissions:
    - Incorporate modern cooling and energy systems, such as geothermal cooling or high-efficiency inverters, into existing structures.
    - Evaluate the structural integrity of buildings to ensure compliance with safety and energy efficiency standards before retrofitting.

Resource optimization

- To **lower the carbon footprint** of retrofitting projects:
    - Salvage materials such as steel, concrete, or wood from old buildings for reuse in new constructions.
    - Recycle or upcycle components such as bricks, tiles, and glass, which can be integrated into the refurbished design.

6.3 Standards for operation and maintenance

6.3.1 Energy management

Real-time monitoring and dynamic energy management

- Use AI algorithms cycle energy according to the loads necessary for intelligent equipment:
    - AI algorithms are mentioned for the analysis of patterns of land-based water demand and will automatically adjust the energy input according to the demand to minimize waste.
    - Applying noncritical loads during off-peak hours will further save on energy costs and ease the pressure on the grid.

6.3.2 Cooling system optimization

Efficient technologies

- **Integrate water cooling systems** and evaporative techniques to reduce energy use.
- **Evaporative cooling techniques**, such as adiabatic cooling, use water evaporation to cool air, cutting energy use by up to 90 per cent.

6.3.3 Resource and waste management

Water conservation

Closed-loop cooling systems can minimize water use by continuously recycling water within the system:

- Collect rainwater through rooftop harvesting systems for cooling purposes, reducing dependence on external water sources.
- Monitor water usage to identify leaks or inefficiencies and take corrective measures.

Implement closed-loop cooling systems and rainwater harvesting installations.

Waste recycling

Establish partnerships with local waste management companies to handle recycling:

- **Electronic waste (e-waste):** Work with certified recyclers to process obsolete servers, storage devices, and other IT equipment responsibly.
- **Construction waste:** Reuse non-electronic materials such as metal, glass, and concrete wherever possible in future projects.

6.3.4 Training and compliance

Skill development

- Provide continuous training for technical teams on energy optimization tools and sustainable practices.

Standards adherence

- Conduct regular audits to ensure compliance with international standards such as ISO 50001 and LEED.

Expected benefits

- **Better energy efficiency**: Best-available-cooling methods such as adiabatic solutions and hot-cold lane containment combined with renewable energy integration (hydropower and solar) can lead to game-changing savings on operational energy costs of between 30 and 50 per cent. These benchmarks are based on ovhcloud in France and Teraco in South Africa and incorporate energy optimization strategies and renewable integration that have significantly improved their Power Usage Efficiency (PUE) and cut their energy costs.
- **Drive for environmental sustainability**: Renewable energy and advanced technology greatly reduce the carbon footprint and the mountain of e-waste, hence propelling GDP or regional sustainability goals further.
- **Infrastructure sturdiness**: Intelligent systems, including AI and IoT, in conjunction with the hybrid grids, gain resilience and define the least downtime, stabilizing the supply of power during breakdowns on the grid.

The green data centre scheme in Uganda has a high potential for sustainable development. It employs energy sources and technologies that reduce energy consumption and operating costs according to global sustainability standards. In making the transition, Uganda not only fulfils its environmental goals, but it also reduces waste and allows better resource use.

A green data centre is assured of sustainability because of energy-efficient systems and expandable designs that ensure continual operation amidst grid interruptions. This further creates jobs in the local communities, boosts cheap energy availability, and brings in a new dimension where waste heat from data centres could be deployed in agriculture or further serve into community facilities-mostly because of its socio-economic development.

These combined with further environmental effort is what smartly puts Uganda at the frontline on a sustainable digital platform within the whole region, thereby welcoming investment and enhancing innovation developments across Africa. It uses a combination of both environmental and community-inclusive standards to strike a balance between technological development and societal welfare while pushing further towards inclusiveness and sustainable development.

Table 5: Challenges and solutions for sustainable data centre development

Category	Identified challenges	Proposed solutions
Location and design	Difficulty in finding locations close to renewable energy sources (solar, hydroelectric).	• Locate data centres in strategic areas such as Karuma (near hydroelectric plants) and Karamoja (regions with high solar potential).
	Climatic zones requiring constant cooling due to high temperatures in lowland areas.	• Prioritize Western Highlands, which offer naturally cooler climates, reducing the need for energy-intensive cooling systems.
	Connectivity constraints with national backbone infrastructure data hubs.	• Select locations near national backbone infrastructure for low-latency connectivity and reduced costs.
Energy resources	Dependence on an unstable power grid, leading to higher costs from fossil fuel generators.	• Develop autonomous microgrids powered by solar farms or local hydroelectric plants to ensure stable and sustainable power supply.
	Low adoption of renewable energy in urban centres due to lack of space for solar setups.	• Build dedicated solar farms on urban outskirts, interconnected to data centres via adapted infrastructure.
Energy efficiency	Inefficient energy use with power usage effectiveness above 2.5 in most existing centres.	• Adopt AI-based energy management technologies and IoT systems for real-time monitoring and optimization of energy use.
	Dependence on outdated cooling systems responsible for major energy losses.	• Install modern cooling solutions such as evaporative cooling or hot and cold aisle containment to maximize thermal efficiency.
		• Modernize electrical infrastructure with high-efficiency inverters and microgrids
	Poor airflow management in IT rooms, leading to high energy losses.	• Optimize airflow with hot and cold aisle configurations and install containment systems to reduce cooling requirements. • Transition to energy-efficient servers and high-density storage solutions (ssds). • Adopt AI-based workload management tools to minimize waste.
Sustainable construction	Significant waste generated during construction phases and high costs associated with transporting non-sustainable materials.	• Use recycled local materials, such as compressed earth bricks and recycled concrete, to reduce the carbon footprint and minimize transportation costs.
	High time and cost for construction in remote or geographically complex areas.	• Use prefabricated modules to speed up construction, reduce on-site waste, and simplify transportation in difficult-to-access areas.

Table 5: Challenges and solutions for sustainable data centre development (continued)

Category	Identified challenges	Proposed solutions
Waste and water management	Insufficient management of water resources and electronic waste, leading to losses and an increased environmental footprint.	• Install closed-loop cooling systems and rainwater harvesting devices to minimize water resource usage.
	Lack of local solutions for effectively recycling electronic waste from data centres.	• Establish partnerships with local companies for recycling electronic equipment and reusing non-electronic materials.
Local skills	Insufficient qualified personnel for the maintenance of complex systems (advanced cooling, IoT management).	• Launch specialized training programmes with local universities to certify technicians on international standards such as ISO 50001 and LEED.
	Lack of stakeholder awareness about the benefits of green data centres.	• Organize awareness campaigns for investors, operators, and regulators to promote the economic and environmental benefits of green data centres.

7 Implementation roadmap

The roadmap outlines a structured and phased approach to transform Uganda's data centres into sustainable, green, and competitive infrastructures. Divided into three phases, it begins with short-term actions focused on laying foundational elements necessary for long-term success.

7.1 Short-term goals (1 to 2 years)

The short-term phase focally sets out to lay the regulatory, technological, and organizational foundation for ecological transition in Uganda's data centre ecosystem.

7.1.1 Establishing a regulatory framework

- **Defining clear standards for performance benchmarks**: Set up an operational PUE target of 1.8 for existing data centres and 1.4 for new data centres with the same guidelines that are followed in countries such as ovhcloud in France and Teraco in South Africa. They reach these standards by using advanced cooling systems and optimized energy loads, which Uganda can put into practice to avoid retrofitting costs.
- **Embedding renewable energy integration**: Require all new and existing data centres with integration solutions such as solar farms, battery storage, and hybrid microgrids to reduce dependence on the national grid. For instance, siting some data centres near Karuma Dam will allow hydropower to be used.
- **Implement e-waste management standards**: Regulatory regime focusing upon the relevant issues of collection, recycling, and reuse of all outdated IT equipment: Initiatives spearheaded by MTN Uganda to create local e-waste processing chains are good examples of the correct path to minimize environmental damage at lower costs.
- **Include sustainable material specifications**: Develop criteria whereby at least 20 per cent of construction material comes from sustainable sources, such as recycled steel or low-carbon concrete, thus achieving resource efficiency and reduction in carbon footprints for new builds.
- **Involve stakeholders in workshops**: Conduct consultative workshops involving chief actors, such as UCC, NITA-U, the international community, to come to agreement on such standards. Learning from the successful engagement in Kenya of worldwide and local experts will also be a good example for Uganda.
- **Provide financial motivation**: Provide tax breaks for investments in energy-efficient technologies and introduce grants covering first costs up to 30 per cent. Modelled after France's CEE programme and Kenya's renewable energy incentives, a programme of such kind allows faster adoption.

7.1.2 Launching pilot projects

- **Identify strategic sites**: Launch pilot initiatives starting from Raxio Data Centre and a NITA-U facility to test innovative green technologies. These provide good opportunities to get the new system assessed in a washer-dried environment.
- **Trial advanced technology**: Deployment of adiabatic cooling and hot/cold aisle containment for energy usage optimization. Link it with IoT and AI systems for real-time energy monitoring and predictive maintenance, as done by Google's deepmind, which saw big savings on cooling costs due to AI-supported adjustments.
- **Implement e-waste recycling solutions**: Establish local chains for the recycling of obsolete equipment at pilot sites, thereby reducing environmental impacts and creating jobs.

- **Participate with local communities in the pilots**: Partner with cooperatives for the creation of reforestation zones or solar farms in close proximity to pilot facilities. Such initiatives do not just promote sustainability but also serve as a cash income for locals.
- **Monitor the pilots**: Monitor the pilot project metrics over 12 months, for instance, show improvement on PUE, energy saved, cost reduction. Kpis may include reductions in kilowatt-hour usage and operational expenses. Depending on the pilot programme, operational-cost savings were reportedly achieved (as high as 15 per cent) in South Africa.

7.1.3 Skills development and awareness

- **Train technicians on green technologies**: Provide specialized training programmes for at least 50 technicians in ISO 50001 standards, LEED certifications, and energy optimization tools. This mirrors Kenya's success, where renewable energy projects were supported by a trained workforce of over 500 technicians.
- **Launch awareness campaigns**: Publicize pilot project successes through media and stakeholder events to attract further investment and support from policy-makers.
- **Update technical education curricula**: Introduce modules on e-waste management and renewable energy into vocational training programmes, ensuring that future professionals are equipped to sustain the green transition.

7.2 Medium-term goals (3 to 5 years)

The medium-term phase entails scaling up green initiatives, integrating renewable energy with all data centres, modernizing infrastructure, and upgrading technical skills, all of which are important in positioning Uganda as a leader in sustainable digital infrastructure.

7.2.1 Integration of renewable energy

Enhanced renewable energy deployment and grid stability will be key components of Uganda's strategy for 100 per cent clean energy supply to data centres which must continuously and reliably operate.

- **Build solar farms**: Urban areas of Kampala and Entebbe will be surrounded by all of Uganda's solar power potentially attracted by solar farms-generally alongside existing buildings on rooftops, supplying green power without demanding actual land. Solar power generally supports hydropower intermittently, depending on if the sun is shining.
- **Hydroelectric plants**: Small-scale hydroelectric plants located in rural areas offer diversification of the energy generating base, which is especially important in grid stabilization. This will provide renewable energy to data centres while positively impacting electricity access by local communities. This is similar to the ADC model of Kenya, under which around 75 per cent of its power it acquires through renewable energy power purchase agreements.
- **Hybrid systems for stability**: Integration of lithium-ion batteries and hybrid microgrids with solar and hydropower assures service continuity during grid disruptions. Energy storage of excess renewable energy affords reduced downtime and backup power. The development of hybrid microgrids has found much of its success in South Africa, where significant reductions in outages were achieved for Teraco using such systems.
- **Improving grid reliability**: Partnering with UETCL to upgrade transmission lines will allow energy loss to be reduced during distribution. More modern grids will ensure that data centres receive energy in a steady manner with minimum disruptions which may interfere with digital operations. Actions must focus on:

- o Establishing hubs that stabilize energy flows close to major data centres.
- o Proposing advanced substations and grid monitoring systems to reduce transmission losses.
- o Developing alternative emergency power routes for mission-critical infrastructure during operational periods to be serviced or repaired.

Along with a food chain of renewable energy and a resilient grid, this model not only ensures the safe operation of data centres, but it will also provide dependable electricity to local businesses and households to spur economic growth.

7.2.2 Data centre infrastructure modernization

The modernization of facilities will not only help in decreasing energy consumption but also offer Uganda's data centres sustainable energies standards the world would meet.

- **New cooling systems**: The energy consumed shall dramatically decrease with the use of next-generation liquid immersion cooling. The system immerses servers in a thermally conductive liquid eliminating the need for conventional air cooling. Energy savings of between 20-30 per cent could be attained, given the experience at ovhcloud in France.
- **Smart energy systems**: An AI-based energy management system will be used to constantly monitor and optimize the power distribution dynamically. These systems analyse real-time data for better energy efficiency and less wastage and strive for the most effective distribution of resources where they are most needed.
- **Adaptation to climate resilience**: fortify facilities against climate-related risks, such as flooding or extreme heat. It is recommended to raise vulnerable data centres and ensure they have well-functioning drainage to avert interruption in operations and are reinforced with building material to avert possible structural damage from disruptions.

7.2.3 Certifications and training

Developing competence and accreditation to promote and maintain global acceptability shall become one of the core requirements of the organization to attain sustainability in competitiveness.

- Getting at least **80 per cent of Ugandan data centres certified with ISO 50001** (energy management) and LEED (sustainable building design) would put Uganda on the map and attract investors that are sensitive to the environment. Certification processes must provide for periodic auditing and review mechanisms to ensure adherence to best practices.
- **Enhancing capacity-building programmes**: Train 150 technicians on cutting-edge energy systems such as AI-based management, hybrid infrastructure maintenance, and waste processing systems. Special training should prepare the staff properly to tackle the challenges posed by managing complex facilities driven by renewable energy.
- **Networking and collaboration with universities**: Together with local universities and technical schools, in collaboration with the government, set up programmes that train green data centre technology specialists. This would ensure the constant availability of skilled personnel being dispatched to meet the growing workforce demands of sustainable digital infrastructure.

7.3 Long-term goals (beyond 5 years)

This long-term vision of Uganda's green data-centres strategy positions the country to one day take up the position of regional leader of sustainable digital infrastructure. Through use of renewable resources, innovation, and good external investments, Uganda will become the role model for green development in Africa.

7.3.1 Building new green data centres

This stage focuses on improving the new green data centres powered with 100 per cent renewable energy and capable of incorporating the latest in sustainable technologies geared at servicing this rising demand without affecting the environment.

- **Planning and construction**: New facilities will employ the prefabricated modular approach to facilitate scalability, cost-effectiveness, and shortened construction timelines. This approach guarantees fast deployment to meet developing data demands while retaining flexibility to adapt to changing technologies. In particular, Teraco sites were strategically placed near major technology hubs in South Africa to attract international clients and match the regional economy's development. Uganda may replicate such a model with a focus on such sites as Kampala, Entebbe, and the budding economic zones to improve accessibility for investors.
- **Renewable energy integration**: These would include a mix of renewable energy sources, notably hydropower, solar farms, and geothermal systems. This option would allow for energy security and a very sharp decline in carbon emissions, which would put Uganda ahead as a sustainable data infrastructure leader.

7.3.2 Attracting foreign investment

Position Uganda as the most attractive site for green digital infrastructure, major endorsements and strategic partnerships by international governments will be required.

- **Eco-friendly branding**: Uganda's green data centre initiatives will be advertised through targeted campaigns on sustainability, cheap energy, and standards compliance such as LEED and ISO 50001. This would attract hyperscale clients seeking eco-friendly data solutions, such as that achieved by ixafrica in Kenya.
- **Hosting international summits**: Uganda will utilize an annual summit on digital sustainability as a platform to showcase the country's achievements and attract foreign investment through partnership synergy with world leaders in sustainable technology. This will encourage direct foreign investment (FDI) and elevate Uganda's reputation as a regional centre for eco-innovation.

7.3.3 Achieving carbon neutrality by 2050

To achieve carbon neutrality by 2035 is a milestone-level ambition, encapsulated in Uganda's nationally determined contributions under the Paris Agreement.

- **Reforestation schemes**: Large-calibre reforestation on large properties, i.e. 500 hectares, could be instrumental in sequestering up to 10 000 tons of CO_2 per annum. Such projects can help reduce emissions while providing employment opportunities for the local communities. For instance, following the reforestation of 220 acres, MTN Uganda eliminated CO_2 equivalent to 1 500 tons per year, albeit this project proves that this methodology could be done more effectively on a much larger scale.
- **Adoption of advanced technologies**: The geothermal cooling solution, modelled from Kenya's Olkaria plant, is yet another confirmation of the key alternative to traditional energy intensive cooling systems. Combining this with other technologies-such as high-capacity battery storage and hybrid grids-will further stabilize energy supply and reduce emissions.

- **Carbon credit programmes**: Uganda will create a localized carbon credit market to fund green initiatives. Businesses and foreign partners can freely invest in the credits, advance sustainable projects, and level their emissions

7.3.4 Ensuring continuous innovation

Innovation forms the foundation for a competitive and sustainable data centre ecosystem. Uganda needs to keep on adopting and developing advanced technologies so as to continue to be on communication leadership position.

- **The integration of AI and IoT**: The introduction of AI tools allows optimization of flows of energy and real-time adjustment of loads at a considerable reduction in operational costs and amplification in efficiency. IoT sensors capture in-depth information on energy use and performance that allows predictive maintenance and minimizes downtime. For example, Google's deepmind shows a 15 per cent reduction in cooling costs after utilizing AI to dynamically adjust parameters based on real-time data.
- **Collaboration with local universities**: Working together with academic institutions will allow for the development of localized software solutions that address Uganda's unique energy-and operational-needs. This arrangement ensures a pipeline of innovation and builds the local talent base.
- **Operational goal**: To reach a PUE of 1.5 by 2030 and continuous optimization, leading to a reduced operational cost of 10 to 20 per cent. This will benchmark Uganda's data centres with international leaders in power efficiency.

7.4 Monitoring and evaluation

Accordingly, there is a need for a properly conceived monitoring and evaluation framework that allows tracking of progress towards the improvement of strategies for sustainability and the determination of success over time.

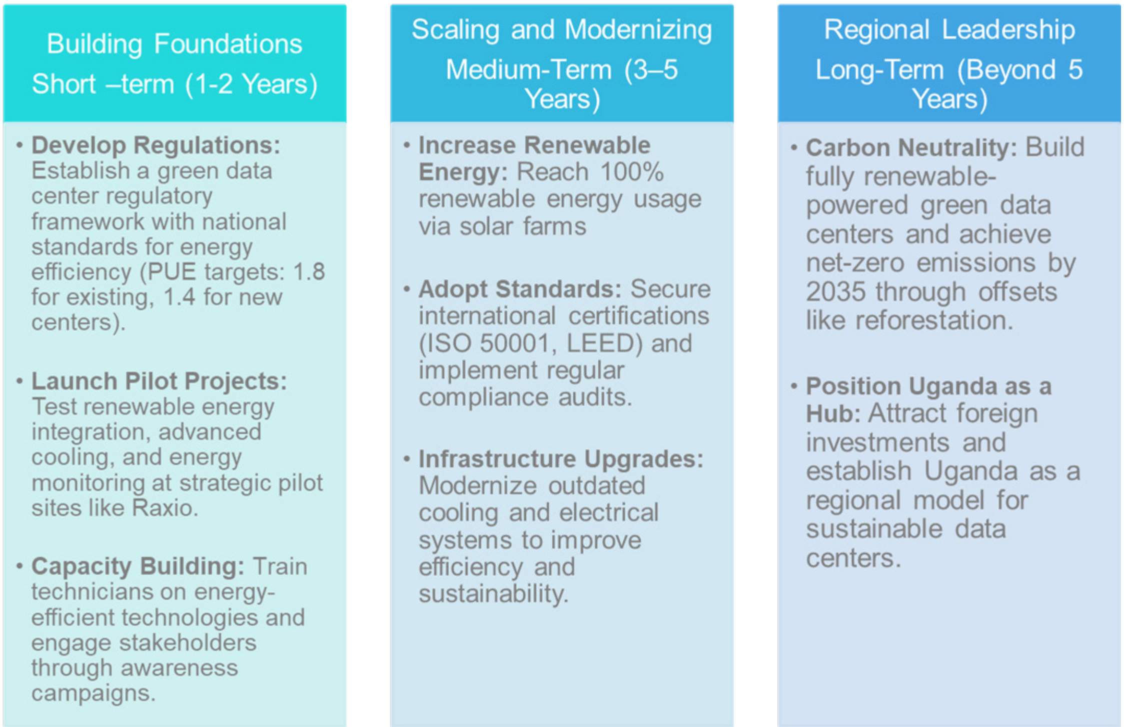
7.4.1 Monitoring tools

Develop a fit-for-purpose monitoring dashboard: Such a system should be established to allow online interaction and monitor key indicators, such as PUE, CO_2 emissions, and renewable energy share. Consequently, this tool will provide actionable insights that will help stakeholders gauge the efficacy of the green initiatives. For example, the sustainable infrastructure dashboards of the European Union set a great example of transparent data-driven monitoring systems.

7.4.2 Continuous evaluation

- **Cycle of annual reviews**: Regular revisions of strategies based on data collected should provide for further emerging opportunities of challenge and change. For example, Singapore revises its energy policies annually to make sure these are in line with evolving climate goals.
- **Feedback mechanisms**: Consultations with stakeholders on at least an annual basis will be undertaken to grow efforts into working towards the refinement of the mission statement to increase efficiency in implementation, including participation of community representatives and industrial leaders.

Figure 6: Roadmap for developing green data centres in Uganda



Source: ITU

8 Conclusion

Uganda stands at an important crossroads where digital innovation and environmental sustainability meet. The green data centre framework and roadmap creates a transformative opportunity for Uganda to meet the growing demand for digital infrastructure while maintaining environmental stewardship. Such a strategy is not merely about technological development, it provides the foundation for Uganda to construct a bigger economic, social, and ecological platform, and its success will lead to the realization of several key benefits.

Modern and efficient green data centres will strengthen Uganda's economic competitiveness, attract investment and position it as a beacon for digital transformation in the Africa region. These facilities provide a solid foundation for fostering innovation that embraces a growing technology ecosystem to deliver cost-effective digital services. Green data centres will also enhance climate commitments and energy security in Uganda through the exploitation of vast renewable energy sources such as solar, hydro, and geothermal resources that will significantly add to energy resilience, ensuring both reliable operations and minimizing reliance on fossil fuels.

This initiative will also enable local communities to have a role in sustainability projects, such as reforestation, e-waste recycling, and skills training within the community, making all communities part of a sustainable transition, and with such developments becoming both a source of employment and an empowerment of individuals so that the benefits from technological advancement are equally spread.

A multi-stakeholder approach is paramount to bring about this ambitious vision:

- Policy-makers prioritize the development of regulatory frameworks that support sustainable practices, spur innovation, and are in line with global standards. Clear guidelines for renewable energy integration, e-waste management, and infrastructure modernization will provide a bedrock for growth.
- Private operators are paramount in driving technological investment and best practice for green operations through innovation and optimization of resources ensuring the importance and longevity of the green data centre initiative.
- International partners provide technical know-how, funding, and examples of successful strategies operating elsewhere. Collaboration with global partners will open a path for Uganda to leapfrog some of its technological barriers to implement cutting-edge solutions.
- Recognizing that local communities are key stakeholders in this transition to green data centres thus highlights an enormous sense of responsibility that Uganda will have toward the transition. Through reforestation, waste management, and training, Uganda continues re-emphasizing collective ownership of green initiatives carried forth by local communities. These will have tangible benefits with regard to improving livelihoods and access to cheap energy and sustainable economic opportunities.

The roadmap for green data centres reflects a bold vision for Uganda's future. It enshrines environmental responsibility in technological advancement, thus ensuring sustainable and inclusive digital transformation. Supporting the multi-stakeholder approach provides Uganda with the opportunity to become the global leader in providing sustainable digital infrastructure. It is clearly more than an infrastructure project, it is a route towards a greener, connected future full of promise for all Ugandans.

Annex 1: Situational and Gap Analysis

1 Introduction

The transition to green data centres in Uganda represents a strategic challenge in the current context of climate change and the pursuit of sustainability in the information technology sector. Uganda has experienced significant growth in its technological infrastructure, particularly in telecommunication networks, data services, and digital platforms, driven by a surge in demand for connectivity and digital services. This rapid expansion has brought about increasing challenges related to energy efficiency, effective resource management, and the reduction of carbon emissions in line with sustainable development goals.

This report aims to analyze the current state of data centres in Uganda, identify existing gaps, and propose recommendations to foster the development of sustainable digital infrastructures. By proactively addressing these challenges, Uganda can establish its technological infrastructure as a model of sustainability within the region and strengthen its resilience against future environmental impacts.

In this report, the term **'sector actor'** refers to any organization, entity, or individual involved in or directly impacted by data centre industry activities. This includes data centre operators, government bodies, regulatory authorities, technology providers, and user companies across various sectors such as telecommunications, banking, and public services. These actors play a key role in the development of standards, the adoption of sustainable practices, and technological innovation within the data centre industry.

1.1 Context of the Project

The project's objective is to support Uganda in defining a green data centre strategy, which is essential to meet international sustainability and energy efficiency standards. Uganda, being rich in renewable resources, has a unique opportunity to leverage these assets to modernize its technological landscape. The first step in this process involves a comprehensive analysis of the current state, followed by a gap analysis to identify major challenges, such as outdated infrastructure, lack of specific regulations, and insufficient stakeholder awareness. This assessment will enable the formulation of concrete recommendations and the design of a viable strategy for the future of data centres in Uganda.

1.2 Objective of the Report

The primary objective of this report is to provide an assessment of the current state of data centres in Uganda by analyzing the existing infrastructure, policies, regulations, and technologies. This analysis aims to identify the barriers and opportunities that can be developed to form the basis for the creation of a green data centre strategy.

1.3 Methodology

The methodology adopted for this study is based on a mixed approach, combining several techniques for data collection and analysis:

- **Interviews**: In-depth interviews were conducted with various stakeholders, including representatives from ministries, regulators, data centre operators, and sustainability experts. These discussions provided diverse perspectives on the challenges and opportunities related to the development of green data centres in Uganda.

- **Literature Review**: A literature review was conducted to gather relevant information from academic publications, government reports, and case studies on best practices in the data centre sector. This review provided essential theoretical and empirical context for the analysis.
- **Gap Analysis**: A gap analysis was then conducted to assess the difference between the current state of infrastructure and international standards and best practices for green data centres. This included an examination of operational practices, energy efficiency, and existing policies.

2 Current State of Data Centres in Uganda

2.1 Existing Data Centre Infrastructure

The data centre infrastructure in Uganda is at a critical juncture, marked by rapid growth but also facing numerous challenges that affect its efficiency and sustainability. This section examines the current state of infrastructure, focusing on key aspects such as equipment, the regulatory framework, access to energy, and the technologies in use.

2.1.1 Outdated Equipment and Technologies

A significant portion of data centres in Uganda still relies on outdated technologies that lead to excessive energy consumption. While some operators, such as MTN, have made strides in upgrading their infrastructure and aligning closer to standards set by advanced centres like Raxio, other centres, particularly those managed by UTEL and NITA-U, continue to operate with older systems. In some instances, equipment over 20 years old has only recently been upgraded, resulting in inefficient Power Usage Effectiveness (PUE) ratings, with some centres exceeding 3.2. Many facilities still use conventional servers and cooling systems that fall short of modern energy efficiency standards. For example, PUE values for certain data centres range between 2.2 and 2.7, while these could be significantly improved with more efficient technologies.

The variability in infrastructure updates, coupled with the absence of recognized certifications such as Tier III or Tier IV in some data centres, impacts the ability of these facilities to attract clients looking for high-quality, sustainable services.

2.1.2 Performance Standards and Regulation

Most data centres are not compliant with modern environmental and performance standards. The current regulatory framework does not provide clear guidelines to encourage sustainable practices, leaving a gap in the expectations of investors and operators. Documents such as the National Environment Act and the Renewable Energy Policy emphasize the need for integrated policies to support sustainability in the data centre sector, but these regulations have yet to be effectively implemented.

Moreover, there is an urgent need for clear guidance from regulatory bodies such as the Uganda Communications Commission (UCC) and the National Information Technology Authority (NITA-U) to establish operational practices that promote innovation and sustainability with regards to data centres.

2.1.3 Energy Access and Dependence

Uganda has considerable potential in renewable energy, about 92 per cent[1] of its electricity coming from renewable sources, primarily hydropower. While the country generates enough capacity to support its growing energy needs, high costs of electricity remain a primary challenge, particularly for energy-intensive operations such as data centres. Additionally, transmission and distribution infrastructure is insufficient, which limits the optimal use of the generated capacity. Frequent power outages and issues with the quality of electricity supply further undermine the reliability of data centre operations.

Additionally, while initiatives are underway to integrate renewable energy sources such as solar, biomass and geothermal implementation remains limited. Industry players like Raxio are beginning to adopt adiabatic cooling systems, but concerns persist regarding the availability and sustainability of the water resources needed for these systems.

2.1.4 Hosting Capacity and Growth

As the demand for digital services continues to rise, the hosting capacity of existing data centres is often insufficient. Many centres, particularly those managed by NITA-U, are already nearing maximum capacity, supporting a growing number of government applications. The current infrastructure does not always meet future market needs, making the development of new facilities crucial.

Data collected from the interview with Raxio[11].

The proposal to build new data centres, such as the ongoing project at NITA-U, presents a unique opportunity to create infrastructures that adhere to sustainability criteria from the design stage, integrating green solutions to reduce environmental impact.

2.1.5 Interoperability and Connectivity

Data centres must also be integrated into a broader infrastructure framework to ensure effective connectivity. Recent guidelines on ICT infrastructure sharing highlight the importance of collaboration among different players to optimize resources and reduce costs. This includes interconnection with the Uganda Internet Exchange Point (UIXP) to facilitate the management of local internet traffic.

2.2 Regulatory Framework and Existing Policies

Uganda's regulatory framework for data centres is still in development, aiming to tackle the challenges of energy efficiency and sustainability in this fast-growing sector. Although there are currently no regulations specific to data centres, various existing policies and initiatives related to infrastructure and environmental management can provide a solid foundation for creating a dedicated framework. These existing regulations offer a basis upon which stakeholders can build sustainable and resilient digital infrastructures.

11 https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=UG

2.2.1 Energy Regulations

Uganda's 2023 Energy Policy aims to ensure a sustainable and equitable energy supply to support economic growth. In 2023, Uganda's electricity production capacity reached over 1,346 MW, mainly due to hydropower, which accounts for about 92 per cent of this capacity. Large-scale projects, such as the Karuma Hydroelectric Power Plant, which adds 600 MW, illustrate the country's commitment to a robust energy infrastructure.

Despite these advances, only 47 per cent[(2)] of the population has access to electricity in 2022 according to World Bank collection of development indicators. This highlights the importance of expanding the electrical infrastructure to meet the growing needs of data centres. Furthermore, the use of other renewable energy sources, such as solar power, remains underutilized, necessitating greater efforts to diversify the country's energy mix.

2.2.2 Promotion of Renewable Energy

Uganda's Renewable Energy Policy introduces incentives, such as Feed-In Tariffs, to encourage investments in renewable energy. These standardized tariffs, applied to renewable energy systems generating up to 50 MW, are designed to ensure the profitability of clean energy projects. Uganda's energy mix is significantly supported by both new and older hydropower plants, which form the backbone of the country's renewable energy generation. Major plants, such as the Bujagali and Karuma dams, have been crucial in increasing generation capacity, while older plants continue to contribute to the national grid.

However, the lack of available space in Kampala and its immediate outskirts makes the installation of solar panels for data centre usage particularly challenging. The success of this policy heavily depends on raising awareness and engaging potential investors. Efforts to promote solar energy and diversify other renewable energy sources need to be intensified so that data centres can fully benefit from these incentives, despite spatial constraints.

2.2.3 Environmental Regulations

The Environmental and Social Assessment Regulations and the National Environment Act mandate that Environmental Impact Assessments (EIAs) be conducted before implementing infrastructure projects, including data centres. However, these requirements are standardized, with no specific guidelines tailored to data centres, despite their distinct environmental impact compared to other types of infrastructure. Developing specific guidelines and recommendations for data centres could help address their unique challenges. While data centres are required to comply with electronic waste management standards, awareness and enforcement of these standards remain limited. Establishing robust systems for recycling and waste management is crucial to mitigating the environmental impact of these facilities.

2.2.4 Government Initiatives

Uganda's Digital Transformation Roadmap includes initiatives aimed at promoting green IT environments, with a focus on creating a framework that supports the adoption of sustainable practices. However, there is a lack of specific financial incentives for companies seeking to adopt these practices.

Aligned with the Third National Development Plan (NDP III), these initiatives form part of Uganda's broader commitment to digital transformation and sustainable development. However, there is a lack of specific financial incentives, such as grants or tax relief, for companies looking to adopt these green practices. Establishing such financial support mechanisms would be crucial in accelerating the shift towards sustainable infrastructures by attracting investments in green technologies.

To facilitate the transition to sustainable infrastructures, it is essential that the government develops incentive programs, such as grants or tax relief, to stimulate investments in green technologies. Additionally, access to land and specific industrial areas where road access is good, redundant power lines are available, and sufficient space exists to implement alternative renewable energy systems would further encourage companies to adopt sustainable infrastructure solutions.

2.3 Key Players in the Sector

The data centre sector in Uganda consists of various actors:

- Data Centre Operators: Both local and multinational companies operate the main data centres. These operators are striving to improve their operational efficiency while facing rising operating costs. They are beginning to recognize the importance of adopting sustainable practices, but this shift still requires substantial support.
- Government: The government, through entities such as the Ministry of ICT, plays a central role in regulating and supporting digital infrastructure. While the 2015 E-Government Regulations do not explicitly encourage the creation of a national data centre, they aim to enhance data security and system interoperability, which may imply the need for such infrastructure.
- User Companies: The companies that rely on data centres for their operations are often medium to large in size, including banks, internet service providers (ISPs), government agencies, and SMEs in sectors like agriculture and healthcare. However, there is a general lack of awareness about the benefits of green data centres. The National Broadband Policy highlights the importance of data centres as part of the ICT infrastructure, but there remains a lack of an integrated strategy for promoting energy efficiency in these facilities.

2.4 Current Technologies and Practices in Data Centres in Uganda

The technologies used in data centres in Uganda vary significantly, with most installations still relying on traditional systems. However, several emerging initiatives and practices indicate a growing potential for integrating more sustainable and efficient solutions. This section covers key themes such as infrastructure, energy efficiency, renewable energy integration, waste management, and data security, considering the current national context.

2.4.1 Infrastructure and Equipment

- **Cooling Systems:** Most data centres in Uganda still depend on traditional, energy-intensive cooling systems. These installations, often using air cooling methods, consume significant amounts of energy, which increases operating costs in a country where electricity supply can be unstable. However, some companies, such as Raxio, are starting to explore more efficient alternatives like indirect adiabatic cooling. The adoption of these technologies is crucial for improving energy efficiency and reducing the carbon footprint of operations.
- **Hosting Capacity and Expansion:** The growing demand for digital services is putting pressure on the capacity of existing data centres. Many centres, including those managed

by NITA-U, are approaching their maximum capacity, making it necessary to develop new infrastructure. This urgent need for modernization must be addressed to ensure Uganda's technological infrastructure can support economic growth.

2.4.2 Energy Efficiency

- **Energy Consumption Monitoring:** Currently, data centres struggle to track and optimize their energy consumption. The use of Energy Management Systems (EMS) and DCIM, Orchestration systems that optimize the use of resources are still limited, preventing operators from maximizing efficiency.
- **Operational Practices:** The use of best operational practices, such as server virtualization, is still rare in the sector. This limits opportunities for energy efficiency improvements and keeps operating costs high.

2.4.3 Renewable Energy Integration

- **Adoption of Renewable Energy Sources:** Most data centres still rely on the national power grid for energy. While some centres have begun integrating solar panels, this practice remains limited. Solar energy is still underutilized, despite Uganda's significant renewable energy potential. One of the key challenges is that data centres require sufficient space to install solar panels, which is difficult to find close to Kampala.
- **Development of Solar Projects**: Ongoing projects aim to develop solar installations, but these are not yet widespread. Data centres struggle to diversify their energy sources away from traditional electricity grids.

2.4.4 Waste Management

- **Electronic Waste Management**: Data centres generate electronic waste, but the management of this waste is not consistently compliant with established standards (2020 Waste Management Regulations). Data centres are required to follow regulations on electronic waste management, but awareness and enforcement of these standards remain insufficient.

2.4.5 Innovations

- Lack of Investment in Cutting-Edge Technologies: There is a lack of investment in advanced technologies, such as high-performance cooling systems, virtualization technologies or IoT systems for the monitoring of data centres.
- The ICT Sector Strategic and Investment Plan highlights the need to train ICT professionals, but the lack of technical expertise remains a challenge.

The current state of data centres in Uganda presents a mix of challenges and opportunities. While the country has taken steps to improve its infrastructure and regulations, a more integrated and proactive approach is needed to develop an effective green data centre strategy. Collaboration between operators, the government, and other stakeholders will be crucial in overcoming the identified obstacles and leveraging the opportunities offered by green technologies.

3 Framework: International Standards and Best Practices for Green Data Centres

3.1 International Standards for Green Data Centres

International standards establish criteria and guidelines for the design, construction, and operation of eco-friendly data centres. Below is an overview of the most relevant standards:

3.1.1 ISO 50001 - Energy Management System

- **Objective**: Help organizations establish an effective energy management system, promoting continuous improvement in energy performance.
- **Application**: By integrating ISO 50001, data centres can reduce energy costs, improve efficiency, and minimize their carbon footprint. This involves adopting practices such as analyzing consumption data and optimizing real-time operations.

3.1.2 LEED (Leadership in Energy and Environmental Design)

- **Objective**: Certify eco-friendly buildings, including data centres, based on criteria such as material sustainability, energy efficiency, and water management.
- **Application**: Data centres that achieve LEED certification demonstrate a commitment to building and operating sustainable facilities. Design and construction requirements include using recycled materials and implementing renewable energy systems.

3.1.3 Green Grid

- **Objective**: Improve the energy efficiency and sustainability of IT infrastructure.
- **Application**: Green Grid provides indicators like Power Usage Effectiveness (PUE), which measures total energy consumption compared to the energy used to power IT equipment. A lower PUE indicates better energy efficiency.

3.1.4 ASHRAE

- **Objective**: Establish recommendations for energy-efficient heating and cooling systems in data centres.
- **Application**: By following this standard, operators can optimize operating conditions, reduce cooling requirements, and lower energy consumption.

3.1.5 BREEAM (Building Research Establishment Environmental Assessment Method)

- **Objective**: Evaluate and certify the environmental performance of buildings.
- **Application**: Data centres adopting BREEAM commit to meeting strict criteria for resource management, water conservation, and waste reduction.

3.1.6 EU Code of Conduct for Data Centres

- **Objective**: The EU Code of Conduct for data centres aims to promote energy efficiency and sustainability in the operation of data centres within the European Union. The initiative encourages operators to adopt practices that reduce energy consumption and minimize environmental impact.

- **Application**: This code provides practical recommendations for data centre operators to improve energy performance. Areas covered include energy management optimization, increased use of renewable energy, and more efficient cooling practices. By following these recommendations, data centres can reduce operating costs and contribute to combating climate change.

3.1.7 ITU and World Bank Guide to Green Data Centres

- **Objective**: This guide addresses the full lifecycle of data centres, from design and procurement to operations and end-of-life management, promoting a circular economy and resilient infrastructure. It emphasizes the importance of climate resilience, sustainable building practices, energy-efficient ICT, e-waste management, and sustainable cooling technologies.
- **Application**: The Guide to Green Data Centres by ITU and the World Bank outlines key actions for sustainable data centres: locate centres in areas resilient to climate risks; adopt modular, energy-efficient designs with sustainable materials; utilize energy-efficient ICT equipment and virtualization to lower consumption; integrate renewable energy sources and water-saving cooling systems to reduce emissions; and encourage sustainable practices through government incentives and green procurement policies to drive eco-friendly industry standards

3.2 Green data centres In Europe

Europe stands out for its innovative initiatives in green data centres, with several countries adopting exemplary regulations and practices. The development strategy for green data centres in Europe is based on a strong regulatory and operational framework, designed to foster energy efficiency and sustainability. The approach adopted integrates several key elements:

- **Proactive Regulation**: Policies from the European Union and national governments focus on reducing energy consumption and increasing the use of renewable energy. These regulations encourage companies to adopt sustainable technologies and invest in energy-efficient infrastructure.
- **Renewable Energy Integration**: The strategy emphasizes the integration of renewable energy sources into data centre operations. This includes optimizing energy management systems to ensure maximum use of renewable resources, contributing to the decarbonization of the sector.
- **Sustainable Design Practices**: Sustainable design principles are at the heart of the strategies for building new data centres. This includes adopting efficient cooling technologies, using eco-friendly materials, and optimizing spaces to reduce the carbon footprint of facilities.
- **Cross-Sector Collaboration**: Cooperation between the public and private sectors is essential to strengthen the infrastructure of green data centres. Strategic partnerships allow sharing best practices and accessing funding for sustainable innovation projects.
- **Awareness and Training**: The strategy also emphasizes the need to raise awareness and train professionals in the sector on sustainability issues. This includes the development of educational programs that incorporate energy management skills and green technologies.

3.3 Incentive Measures for the Development of Green Data Centres

The adoption of green data centres in Europe is supported by a range of incentives that encourage the transition towards sustainable and efficient infrastructures. These measures are crucial for motivating companies to invest in environmentally friendly technologies and improving their energy performance. The main incentives include:

- **Grants and Financial Aid**: Many European countries offer grants and financial assistance to companies investing in green technologies. These programs aim to offset the initial costs associated with the installation of energy-efficient equipment, such as advanced cooling systems or renewable energy installations.
- **Tax Credits and Reductions**: European governments provide tax credits to encourage investments in energy efficiency. These measures allow companies to deduct a portion of their expenses related to sustainable technologies from their income taxes, reducing the overall cost of the projects.
- **Standards and Certifications**: Certifications like ISO 50001 offer competitive advantages to data centres that comply with strict ecological standards. Companies can benefit from tax reductions or grants by obtaining these certifications, thus incentivizing the adoption of sustainable practices.
- **Easier Access to Financing**: The European Union and national governments offer specific financing programs for energy efficiency projects. These initiatives facilitate access to low-interest loans or investment funds dedicated to green technologies.
- **Public-Private Partnerships**: Collaboration between the public and private sectors is encouraged to develop sustainable infrastructure projects. These partnerships allow for cost-sharing and resource pooling, while promoting innovation and technology transfer.
- **Awareness and Training Programs**: Educational initiatives are in place to raise awareness among data centre managers about the benefits of energy efficiency and sustainable practices. These programs help foster a culture of innovation and continuous improvement within organizations such as C-Net Training Program, Sustainable Digital Infrastructure Alliance (SDIA), DatacentreDynamics (DCD) Sustainability Series, climate neutral data centre pact.

4 Uganda's National Objectives

4.1 Uganda's Energy and Climate Objectives

Uganda has committed to ambitious goals for sustainable development and greenhouse gas emissions reduction. By adhering to the Paris Agreement, the country has set nationally determined contributions, which include specific commitments to reducing emissions in the energy, agriculture, and waste sectors. These efforts are aimed at aligning national development with the Sustainable Development Goals (SDGs), particularly SDG 7, which advocates for access to reliable, sustainable, and modern energy for all.

The Uganda National Climate Change Policy highlights the need for a coordinated approach to achieving sustainable development in the face of climate change. The government has identified the importance of integrating climate considerations across all sectors, reinforcing the role of renewable energy and energy efficiency in the national strategy.

4.2 Energy Transition Policies and Use of Renewable Energy

Uganda has developed several policies to promote energy transition and renewable energy usage:

- Uganda Energy Policy 2023: This policy aims to increase the share of renewable energy in the country's energy mix. With 92 per cent of electricity production capacity based on renewable sources, mainly hydropower, the country seeks to further diversify its energy supply by including sources such as solar energy, geothermal energy, and waste-to-energy projects.

- Uganda Green Growth Development Strategy (UGGDS): In alignment with the Sustainable Development Goals, this strategy promotes green growth by integrating energy efficiency and the use of renewable energy across all sectors, fostering an integrated approach to addressing environmental challenges.

4.3 Relevance of Green Data Centres in Uganda's National Energy Strategy

Green data centres are strategically important for achieving Uganda's energy and climate objectives, as they offer several key benefits:

- **Compliance with International Commitments**: By integrating energy-efficient technologies and renewable energy sources, green data centres help Uganda meet its commitments under the Paris Agreement and achieve its nationally determined contributions. This includes reducing the carbon footprint and improving energy efficiency in the information technology sector.
- **Support for Digital Transformation**: Uganda's Digital Transformation Roadmap emphasizes the need to improve digital infrastructure, including data centre development, to enhance public service efficiency. Green data centres can play a key role in managing government data, ensuring service continuity, and facilitating the transition to digital governance.
- **Boosting Innovation and the Green Economy**: The development of green data centres contributes to technological innovation, creating jobs in green technologies and stimulating economic growth. The UGGDS emphasizes sustainable resource management, and green data centres can help achieve this goal by reducing energy consumption and integrating sustainable practices.
- **Improving Resilience**: Green data centres could strengthen Uganda's energy infrastructure resilience by integrating renewable energy sources, such as solar and hydropower, reducing dependency on the national grid and allowing operations during power outages. These centres could optimize energy efficiency through eco-friendly technologies, reducing strain on the grid during peak demand. By adopting responsible waste management practices, they could minimize environmental impact and protect natural resources. Additionally, their design could include measures to adapt to extreme weather conditions, ensuring functionality in adverse environmental events. Lastly, these facilities could serve as innovation platforms for testing new sustainable technologies, contributing to national energy efficiency and a more resilient energy infrastructure.
- **IT for Green**: There is significant potential for **IT for Green**, with data centres playing a pivotal role in advancing sustainability across multiple sectors. Data centres can become the backbone of efforts to green agriculture through smart farming technologies, support climate science with large-scale data analysis, promote paperless operations, and enable remote working. By adopting energy-efficient practices, data centres can reduce their environmental footprint while driving green innovations in industries that rely on digital infrastructure.

5 Results of Stakeholder Consultations

5.1 Summary of Interviews with Ministries and Regulators

Interviews were conducted with various ministries and regulatory agencies, including the Ministry of Environment, Uganda Communications Commission (UCC), and the National Environment Management Authority (NEMA). Below is a summary of key observations:

5.1.1 Ministry of Environment

- **Interviewee**: Member of the IT team

The Ministry of Environment plays a critical role in regulating environmental practices in Uganda, particularly concerning the development of ICT infrastructure and data centres. Several key points were discussed during the interview:

- **Role and Responsibilities**: The ministry is responsible for implementing environmental policies, ensuring that development projects, including data centres, adhere to environmental standards and support sustainable development. They play a crucial role in assessing the environmental impacts of new infrastructures.
- **Existing Infrastructure**: The ministry has its own data centre, with backups stored in NITA's data centre. However, it was indicated that hosting the main data centre in an infrastructure operated by NITA does not seem viable.
- **Exploring Renewable Energy Solutions**: The ministry is considering the use of solar energy as an alternative power source for its data centre operations. However, no concrete measures have been implemented yet, presenting an opportunity to align their objectives with sustainable development initiatives.
- **Lack of Specific Recommendations**: The ministry has not yet established guidelines or recommendations regarding green data centres, which could hinder the development of sustainable solutions in this sector.

- **Identified Obstacles**:
  - **Lack of Guidelines on Eco-Friendly Cooling Systems**: The absence of a formal strategy for eco-friendly cooling systems in data centres limits the adoption of sustainable practices.
  - **Limited Knowledge of Best Practices**: The ministry acknowledged a lack of awareness and expertise regarding the best international practices for green data centres, which affects their ability to formulate relevant policies.

5.1.2 Uganda Communications Commission (UCC)

- **Interviewees**:
  - 3 members of the "Engineering Department"

The Uganda Communications Commission (UCC) is the regulatory authority responsible for overseeing Uganda's communications sector, which encompasses telecommunications, broadcasting, radio communication, postal services, data communication, and infrastructure, including data centres. Several essential points were addressed during the interview:

  - **Role and Responsibilities**: UCC oversees and regulates the telecommunications sector. Their mandate includes managing spectrum resources, developing fixed and wireless networks, and protecting consumer interests.
  - **Current Regulatory Status**: UCC noted that there is no specific regulation for data centres at present, as this is not considered an immediate priority. Their focus is primarily on improving coverage in underserved areas, meaning data centre development lacks a clear regulatory framework.
  - **Spectrum Resource Management**: UCC emphasized that improving telecommunications coverage in rural areas is critical to facilitating data centre development. They are working on policies that encourage the efficient use of spectrum resources to maximize access to ICT services.

- **E-waste and Regulation**: UCC stressed the need for a collaborative approach with NEMA to manage electronic waste, an increasing issue with the rise of technological equipment. UCC recognizes that e-waste management must be integrated into data centre development to minimize environmental impact.
- **Incentives for Green Data Centres**: UCC mentioned that the idea of tax incentives to promote the creation of green data centres should be discussed between the Ministry of ICT and the Ministry of Finance. UCC acknowledges that incentive measures could encourage investment in sustainable infrastructure.

- **Identified Obstacles**:
  - **Lack of Relevant Local Content**: The absence of locally relevant content and technological solutions hinders the development of sustainable infrastructure.
  - **Digital Literacy**: Developing basic ICT skills is critical, as the lack of knowledge about digital technologies limits the engagement of sector stakeholders.

5.1.3 National Environment Management Authority (NEMA)

- **Interviewees**:
  - 3 Environmental Officers

NEMA plays a crucial role in promoting sustainable practices and managing environmental impacts in Uganda. Several key points were discussed during the interview:

- **Role and Responsibilities**: NEMA is responsible for implementing and monitoring environmental policies in Uganda, ensuring sustainable development. The agency recently established a new Compliance Assistance Unit – "Greener Economy – Cleaner Production," focusing on helping businesses adopt environmentally friendly practices.
- **E-waste Management**: NEMA highlighted electronic waste management as a growing issue with the increasing number of technological devices. NEMA operates a national e-waste management centre and stressed the need for a robust regulatory framework to handle such waste. New regulations are expected by March 2025, aiming to make recycling economically viable and encourage sustainable practices among businesses.
- **Importance of Environmental Regulations**: NEMA emphasized that data centres must comply with existing environmental regulations, including protecting sensitive areas and minimizing biodiversity impacts. The agency is considering developing specific guidelines for data centres to ensure their development aligns with environmental standards.

- **Identified Obstacles**:
  - **Lack of Inter-Agency Synergy**: Insufficient collaboration between government agencies makes it challenging to implement integrated policies for sustainable data centres.
  - **Inadequate Regulations**: The absence of a specific framework to encourage investment in green data centres creates a regulatory gap.
  - **E-waste Management Challenges**: Managing electronic waste is complicated by a lack of robust policies to ensure the sustainable operation of data centres.

5.2 Summary of Interviews with Data Centre Operators

5.2.1 MTN

- **Interviewee**:
  - Manager of Mechanical Engineering and Data Centre

MTN operates several data centres, primarily serving banks, SMEs, and government services. The company aspires to operate entirely on green energy by 2040. To achieve this ambitious goal, MTN has implemented several initiatives:

- **Energy Transition**: MTN has begun replacing outdated air-conditioning units with more energy-efficient equipment, contributing to reducing their carbon footprint. Additionally, they plan to install solar panels to supplement their energy supply.
- **Improving Energy Efficiency**: The company is conducting studies to improve its Power Usage Effectiveness (PUE) to measure and optimize energy consumption. This initiative aims to ensure that their data centre operations are both sustainable and economically viable.
- **Energy Redundancy Challenges**: MTN faces significant challenges related to energy redundancy, as dependence on a single energy provider in Uganda limits their options. This poses a risk to service continuity in the event of power outages or provider failures.
- **Infrastructure Impact**: MTN highlighted the need for more robust and diversified energy infrastructure to support the expansion of their operations. They also expressed the need for clearer regulations to encourage the adoption of sustainable energy solutions.
- **Commitment to Sustainability**: In addition to their efforts to improve the energy efficiency of their facilities, MTN is committed to raising awareness among their clients and partners about the importance of sustainability and resource management, contributing to a shift towards greener practices in the sector.

- **Challenges Faced**:
  - Skill set and mindset challenges:
    - Lack of necessary skills among staff.
    - Resistance to change from both clients and staff.
  - Cost of certifications and training:
    - High expense of certifications and courses.
    - Limited application of sustainable strategies after certification, with only a few takeaways being implemented.
  - Economic viability based on data centre size:
    - Solutions for greener data centres vary depending on their size.
    - Technologies like adiabatic cooling are only cost-effective for larger data centres, making them less accessible to smaller facilities.
  - Tailored approach needed:
    - Solutions should be scalable and adapted to the size and capacity of each data centre.
    - Addressing both skills and mindset issues is key to promoting greener practices.

5.2.2 Raxio

- **Interviewees**:
  - General Manager
  - VP Technology and Operations

Raxio is Uganda's first carrier-neutral data centre, adopting sustainable and innovative practices. Several key points were addressed during the interview:

- **Role and Operational Characteristics**: Raxio operates a carrier-neutral data centre, allowing various telecommunications operators to access its facilities without favoritism. This promotes competition and improves ICT services' efficiency in the region.
- **Sustainable Technologies**: Raxio leverages renewable energy, accounting for more than 90 per cent of Uganda's energy supply. They also use an indirect adiabatic cooling system, which consumes less energy and can achieve energy efficiency up to six times greater than conventional air-conditioning systems. This combination of smart technologies and sustainable practices positions Raxio as a leader in energy-efficient data centres in the region.
- **Vision for Green Data Centres**: Raxio is committed to promoting green data centres in Uganda. However, they identified several major obstacles to their strategy:
    - **Customer Mindset**: Many clients prefer to have data centres near their offices rather than opting for colocation solutions, limiting the expansion of neutral facilities.
    - **Lack of Skills**: There is insufficient technical skills development in the sector, complicating the integration of modern and sustainable technologies.
    - **Lack of Favorable Policies**: Raxio pointed out that the absence of clear and incentivizing policies from the government to support investment in sustainable infrastructure is a barrier to the development of green data centres. They emphasized the need to bring stakeholders together to establish sustainable ICT solutions in Uganda.

- Challenges Faced:
    - **Investment Costs**: Although Raxio is willing to invest in sustainable technologies, the costs associated with upgrading infrastructure and adopting eco-friendly practices are substantial.
    - **Regulatory Compliance**: The lack of specific regulations for data centres, including guidelines on energy efficiency and sustainability, poses a challenge for implementing best practices.

5.2.3 NITA-U

- **Interviewee**:
    - Data Centre Manager

NITA-U, established in 2009, is the central authority responsible for streamlining ICT services across government agencies in Uganda. Several important points were discussed during the interview:

- **Role and Responsibilities**: NITA-U manages two data centres, one serving as a backup for the other. These centres are fully utilized, hosting 30 racks and currently supporting 300 government applications, with the goal of reaching over 450 applications within the next two years. One-third of all government agencies are currently hosted on these infrastructures.
- **Vision for Green Data Centres:** Although NITA-U has plans to build a new data centre that will be twice the size of the current one, there is no formal strategy yet for greening operations. Their data centres are designed to meet Tier III requirements, but they have not yet obtained this certification.

- **Identified Obstacles**:

- **Lack of Skills**: One of the main challenges is the lack of training and skills in staff to integrate sustainable practices and new technologies.
- **Lack of Synergy**: The absence of coordination between government agencies, such as NITA and NEMA, hinders efforts to promote green data centres. This reduces the effectiveness of environmental and ICT policies.
- **Development Opportunities**: NITA-U noted that there is still an opportunity to influence the design of the new data centre. This represents a chance to integrate sustainability criteria and eco-friendly practices from the outset.
- **Regulatory Challenges**: The lack of specific regulations on green data centres and the absence of clear guidelines limit their ability to implement significant changes. Currently, there are no ongoing projects or discussions regarding other private actors interested in setting up a neutral data centre in Uganda.

5.2.4 UTeL

- **Interviewees**
    - Technical Operations Director

UTEL is a telecommunications operator providing mobile voice and fixed data services in Uganda. During the interview, several key points were discussed:

- **Role and Services Provided**: UTEL offers mobile voice services via a 2G network, as well as fixed data services through fiber optics and wireless technologies using unlicensed spectrum (5 GHz). They also offer mobile money services, reflecting their involvement in the digital financial sector.
- **Existing Infrastructure**: UTEL has a fiber network deployed in several cities, including Kampala, Jinja, Mukono, and Mbale. Although they have several technical rooms for hosting servers, they do not currently operate full-scale data centres. However, they have land available in various regions, which could accommodate new data centres.

- **Challenges Related to Green Data Centres**:
    - **Outdated Equipment**: One of the main challenges for UTEL is the presence of legacy equipment and old buildings, making it difficult to upgrade their current facilities to meet green data centre standards. It would be easier to build a new data centre that meets environmental requirements than to renovate existing installations.
    - **Insufficient Expertise**: The staff needs significant training to master new technologies and sustainable practices. The lack of expertise in handling legacy equipment is a major obstacle to transitioning to greener solutions.
- **Investment Needs**: UTEL acknowledges that substantial investments would be required to develop data centre infrastructures that meet ecological standards. The costs associated with these investments may be prohibitive.

5.3 Summary of Stakeholder Expectations and Concerns

In the context of developing green data centres in Uganda, stakeholders, including ministries, regulators, and data centre operators, have expressed significant expectations and concerns. These points reflect their desire to establish a favorable environment for adopting sustainable practices while highlighting the challenges to overcome to meet these objectives.

5.3.1 Expectations

- **Strong Regulatory Framework**: Stakeholders desire a clear regulatory framework that encourages investment in sustainable infrastructure, providing specific guidelines for the development of green data centres.
- **Tax Incentives**: There is a pressing need for tax incentives for companies that adopt sustainable and environmentally friendly practices. This includes tax relief for investments in green technologies.
- **Training and Skills Development**: Stakeholders expect training programs to improve the technical skills of employees. This will help integrate sustainable practices into the daily operations of data centres.
- **Inter-Agency Collaboration**: Stakeholders hope for better synergy between different government agencies, such as NEMA, UCC, and the Ministry of Environment, to coordinate efforts aimed at promoting green data centres.
- **Sustainability Awareness**: Stakeholders want increased awareness of the benefits of green data centres, both for businesses and the general public, to foster a mindset shift towards more sustainable solutions.

5.3.2 Concerns

- **Limited Government Support**: Stakeholders express concerns about the lack of concrete government support for developing eco-friendly and sustainable infrastructure.
- **Absence of Specific Regulations**: The lack of clear regulations concerning data centres and sustainable practices limits their development and creates a regulatory gap.
- **High Costs**: The costs associated with certifications, staff training, and equipment upgrades pose significant financial barriers for companies seeking to adopt eco-friendly practices.
- **Limited Expertise**: Stakeholders emphasize the urgent need for technical skills in the sector, noting that the lack of expertise in modern technologies hinders the development of sustainable infrastructure.
- **E-Waste Management**: E-waste management remains a significant challenge. The lack of rigorous policies limits the establishment of sustainable practices in the information technology sector. Environmental regulations require producers and distributors of electronic products to take responsibility for the waste generated by their products, by setting up collection centres and suitable return systems. Local governments are also encouraged to establish collection centres and may offer incentives to encourage the public to properly dispose of electronic waste.
- **Client Mindset**: Stakeholders, particularly Raxio, point out that clients' preference for data centres located close to their offices limits the development of neutral data centres.

6 Gap Analysis

This chapter examines the current state of data centres in Uganda, evaluating their compliance with sustainability goals and international standards. It identifies gaps in infrastructure, regulatory frameworks, technical skills, and financing, highlighting the challenges to be addressed and the opportunities to be leveraged to promote the development of green data centres.

6.1 Infrastructure and Energy Efficiency

Uganda's data centre infrastructure heavily relies on conventional technologies, presenting a significant challenge in achieving optimal energy efficiency. Most facilities operate with outdated equipment that does not meet modern standards.

6.1.1 Current State of Infrastructure

- **Obsolete Equipment**: Many data centres in Uganda use old air conditioning systems and servers, which are often inefficient, leading to higher operational costs and a larger carbon footprint. The reliance on traditional energy-intensive cooling technologies is a major barrier to optimizing energy efficiency.
- **Ongoing Initiatives**: Operators like Raxio are setting an example by investing in more sustainable cooling technologies, such as indirect adiabatic cooling systems. While these systems significantly reduce energy consumption compared to conventional methods, they also require substantial water usage, raising concerns about sustainability, particularly in regions with limited water access. Additionally, the absence of recognized certifications, such as Tier III, in several facilities limits their operational efficiency and ability to attract clients seeking reliable and sustainable solutions.
- **Modernization Needs**: Upgrading existing infrastructure to integrate energy-efficient solutions is crucial to enhance the resilience of data centres to climate challenges. Necessary actions include:
  - **Equipment Upgrades**: Replacing outdated technologies with more modern, energy-efficient systems, such as low-energy servers and optimized cooling units.
  - **Eco-Design Adoption**: Incorporating eco-design principles during infrastructure planning to minimize environmental impact throughout the facility's life cycle. This includes:
    - **Sustainable Materials**: Using materials with low environmental impact and promoting recyclability.
    - **Modularity**: Designing modular systems that allow easy adaptation and expansion of infrastructure based on changing needs without full reconstruction, optimizing resources and reducing waste.
    - **Resource Management Optimization**: Maximizing efficiency in the use of water and energy.
- **Adopting Sustainable Operational Practices**: Implementing management practices that reduce energy and water consumption, along with waste management strategies to minimize environmental impact.
- **Integrating Security and Redundancy**: Strengthening physical and software security, ensuring redundancy to prevent service outages. Backup and disaster recovery systems are essential to guarantee operational continuity.
- **Lack of Awareness and Information**: Operators may not be fully informed of best practices and emerging technologies that could improve energy efficiency. Raising awareness of these solutions is essential to encourage their adoption.

6.1.2 Opportunities

- **Access to Renewable Energy**: With more than 90 per cent(2) of its electricity generation capacity coming from renewable sources, Uganda has the opportunity to leverage these resources to reduce the operational costs of data centres and improve long-term sustainability.

Data collected from the interview with Raxio[12]

- **Innovative Technologies**: The rapid advancement of technologies, such as artificial intelligence and the Internet of Things (IoT), offers possibilities for optimizing resource management and improving the operational efficiency of data centre infrastructures.

6.2 Regulatory and Policy Frameworks

The regulatory and policy framework for data centres in Uganda is currently insufficient and lacks specific guidelines. While ministries and agencies such as UCC, NEMA, and NITA-U recognize the need for a framework that promotes investment in green data centres, there are significant gaps that need to be addressed.

6.2.1 Current Regulatory Framework

- **Lack of Specific Regulations and Policies**: Currently, there are no clearly defined policies or regulations to encourage the creation and operation of green data centres. This regulatory gap discourages investors and limits the sector's growth. Companies do not have clear guidelines on energy efficiency, waste management, or carbon emissions reduction standards.
- **Lack of Inter-Agency Synergy**: Cooperation between different government agencies is often limited. For example, the lack of effective collaboration between NEMA and NITA-U makes it difficult to develop integrated policies that could promote sustainability. This lack of synergy hampers efforts to create an environment conducive to green data centres.

6.2.2 Identified Gaps

- **Regulatory Uncertainty and Compliance Issues**: The stakeholders face regulatory uncertainty that hinders investment. The absence of specific standards for green data centres makes it difficult to implement compliance mechanisms. This can lead to inefficient and environmentally harmful practices, discouraging companies from adopting sustainable technologies.

6.2.3 Opportunities

- **Establishment of a Clear Regulatory Framework:** Introducing specific regulations could not only strengthen investor confidence but also create incentives for companies to adopt sustainable practices. This could include minimum energy efficiency standards, waste management requirements, and guidelines on water resource use.
- **Development of Public-Private Partnerships**: Encouraging partnerships between the public sector and private actors could foster support programs that promote innovation and the adoption of sustainable technologies. These collaborations could also include financing initiatives, such as grants or low-interest loans for green projects.
- **Awareness and Education:** A campaign to raise awareness among stakeholders about the importance of green data centres could play a key role in developing a solid regulatory framework. Educating investors and consumers on the benefits of sustainable infrastructures –meaning projects designed to minimize environmental impacts, conserve natural resources, and promote resilience to environmental changes– can create increased demand, driving the development of favorable policies.

[12] Data collected from the interview with Raxio

6.3 Technical Skills and Training

The transition to green data centres requires specific technical skills, which are currently lacking in Uganda. Sector actors, including NITA-U, MTN, and UTEL, emphasize the critical need for training in modern technologies and sustainable practices. Developing these skills is essential to ensure that staff can manage technological infrastructures effectively while adhering to sustainability standards.

6.3.1 Current State of Skills

- **Limited Digital Literacy**: There is a widespread lack of knowledge about advanced technologies and best practices for operating data centres, which hinders the engagement of sector actors. This skills deficit limits the adoption of innovative solutions that could improve energy efficiency and reduce environmental impact.
- **Insufficient Training**: There is an urgent need for training programs for data centre staff to equip them with the necessary skills to operate and maintain sustainable infrastructures. Most institutions do not offer specific training in green technologies, leaving staff unprepared for the challenges of the energy transition.

6.3.2 Identified Gaps

- **Lack of Specialized Training**: Existing training programs in UGANDA do not address the specific needs of data centres regarding sustainability and energy efficiency. The absence of clear training pathways for green technologies and modern infrastructure management creates a gap between sector requirements and available skills.
- **Challenges in Accessing Continuing Education**: IT professionals often face difficulties accessing continuing education programs on technological innovations and sustainability best practices due to factors such as high program costs, limited availability of relevant courses, scheduling conflicts with work commitments, and a lack of employer support or incentives for professional development.

6.3.3 Opportunities

- **Partnerships with Educational Institutions**: Developing partnerships with local universities and international organizations could facilitate the implementation of targeted training programs. These collaborations could also create curricula tailored to the specific needs of the data centre sector in Uganda.
- **Online Training and E-Learning**: Using online learning platforms can also be an effective solution for training a larger number of professionals, providing access to resources and courses on green technologies and eco-design.
- **Certification Programs**: Establishing certification programs for sustainable practices and green technologies could encourage professionals to acquire the skills needed to improve the operational efficiency of data centres.

6.4 Financing and Investments

The development of green data centres in Uganda requires significant investments. Sector actors such as MTN, Raxio, and NITA-U express concerns about the high costs associated with implementing sustainable solutions.

6.4.1 Current State of Financing

- **High Investment Costs**: The expenses related to acquiring new technologies, upgrading existing infrastructures, and obtaining ecological certifications can be major financial barriers for companies. For instance, compliance costs for Tier III or Tier IV standards can be prohibitive, discouraging the necessary investments to modernize facilities. Companies often hesitate to engage in costly projects without long-term return on investment guarantees.
- **Lack of Financial Incentives**: The absence of government financial support for sustainability projects limits companies' investment capacities. Measures such as grants, tax breaks, or low-interest loans for green initiatives are practically non-existent, making it difficult to access the capital needed to adopt green technologies.

6.4.2 Identified Gaps

- **Financial Uncertainty**: The fluctuation of energy costs and resources necessary for data centres, combined with the lack of financial support, creates uncertainty that discourages companies from investing in sustainable infrastructure. Market players need clear visibility of long-term costs to justify their investments.

6.4.3 Opportunities

- **Innovative Financing Mechanisms**: Establishing alternative financing mechanisms, such as government grants or public-private partnerships, could stimulate investments in the sector. Low-interest loans or loan guarantees for companies investing in green technologies are potential solutions to explore.
- **Collaboration with Foreign Investors**: Attracting foreign investment to develop sustainable infrastructure could also represent an opportunity. Facilitating partnerships with international companies experienced in green technologies could bring additional capital and technology transfer to Uganda.
- **Raising Awareness of Sustainable Investment Importance**: Promoting the economic and environmental benefits of green data centres to investors and decision-makers could foster a greater willingness to invest. Case studies showing the return on investment from sustainable infrastructure could be presented to encourage the adoption of similar practices.

7 Barriers and Opportunities for the Development of Green Data Centres

The development of green data centres in Uganda faces a complex set of barriers that hinder the transition to sustainable infrastructures. These challenges include technical, infrastructural, regulatory, and political obstacles, but they coexist with significant opportunities that can be leveraged.

7.1 Barriers

- **Obsolete Equipment**: Many data centres rely on outdated technologies that consume excessive energy and fail to meet modern efficiency standards. Replacing these systems with more energy-efficient solutions requires significant investments, which operators often perceive as too risky.
- **Lack of Standards and Certifications**: The absence of recognized certifications limits the ability of data centres to attract clients seeking reliable and sustainable solutions. Without clear standards, operators find it challenging to justify the costs related to upgrading their infrastructure.

- **Water Consumption**: Cooling systems, particularly those using adiabatic methods, can lead to significant water consumption. This presents challenges, especially in regions where water access is limited, increasing the need for innovations to reduce dependence on water while maintaining adequate cooling performance.
- **Lack of Government Support and Financial Incentives**: The absence of clear policies favoring the creation and operation of green data centres prevents the necessary investments. Sector players do not benefit from financial incentives such as subsidies or tax relief, making infrastructure modernization more difficult.
- **Insufficient Inter-Agency Coordination**: The lack of effective collaboration between various government agencies, such as NEMA and NITA-U, complicates the implementation of integrated policies. Better synergy between these agencies is essential to establish a coherent framework and encourage investments in sustainable infrastructure.
- **Regulatory Uncertainty**: The lack of clear guidelines creates an atmosphere of uncertainty for investors, who are hesitant to commit to modernization projects without guarantees regarding future sustainability requirements.
- **Challenges in Accessing Training and Education**: The transition to greener technologies requires specific technical skills that the current workforce may not possess. Companies need to invest in training their personnel to ensure they are equipped to handle new technologies and apply best practices in sustainability.

7.2 Opportunities

Despite these barriers, several opportunities can be leveraged to encourage the development of green data centres in Uganda:

- **Integration of Renewable Energy**: With more than 90 per cent of the country's electricity coming from renewable sources, data centres have the opportunity to reduce their carbon footprint and operational costs. The adoption of solar energy solutions and other renewable resources could enhance operational sustainability.
- **Technological Innovation**: The emergence of technologies such as artificial intelligence (AI) and the Internet of Things (IoT) offers opportunities to optimize resource management and improve operational efficiency. These technologies can facilitate the monitoring and automation of systems, allowing for more effective energy management.
- **Public-Private Partnerships**: Promoting collaboration between the government and the private sector could stimulate sustainability initiatives. These partnerships could include financing programs to help companies invest in green technologies.
- **Awareness and Education**: Promoting the economic and environmental benefits of green data centres can generate greater interest among investors and policy-makers. Awareness campaigns and training programs for sector actors are essential to create a conducive environment for innovation and the adoption of sustainable practices.
- **Incentive-Based Regulations**: The establishment of specific regulations that promote the use of green data centres could improve the situation. For example, introducing fiscal incentives for companies investing in sustainable technologies could boost the market.

The development of green data centres in Uganda is hindered by a complex set of technical, infrastructural, regulatory, and political barriers. However, by identifying and overcoming these obstacles while capitalizing on existing opportunities, Uganda can move towards more sustainable digital infrastructure. Stakeholder engagement strengthened cooperation between the public and private sectors, and increased awareness of the benefits of sustainable practices will be crucial for a successful transition.

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Annex 2: Benchmark Report

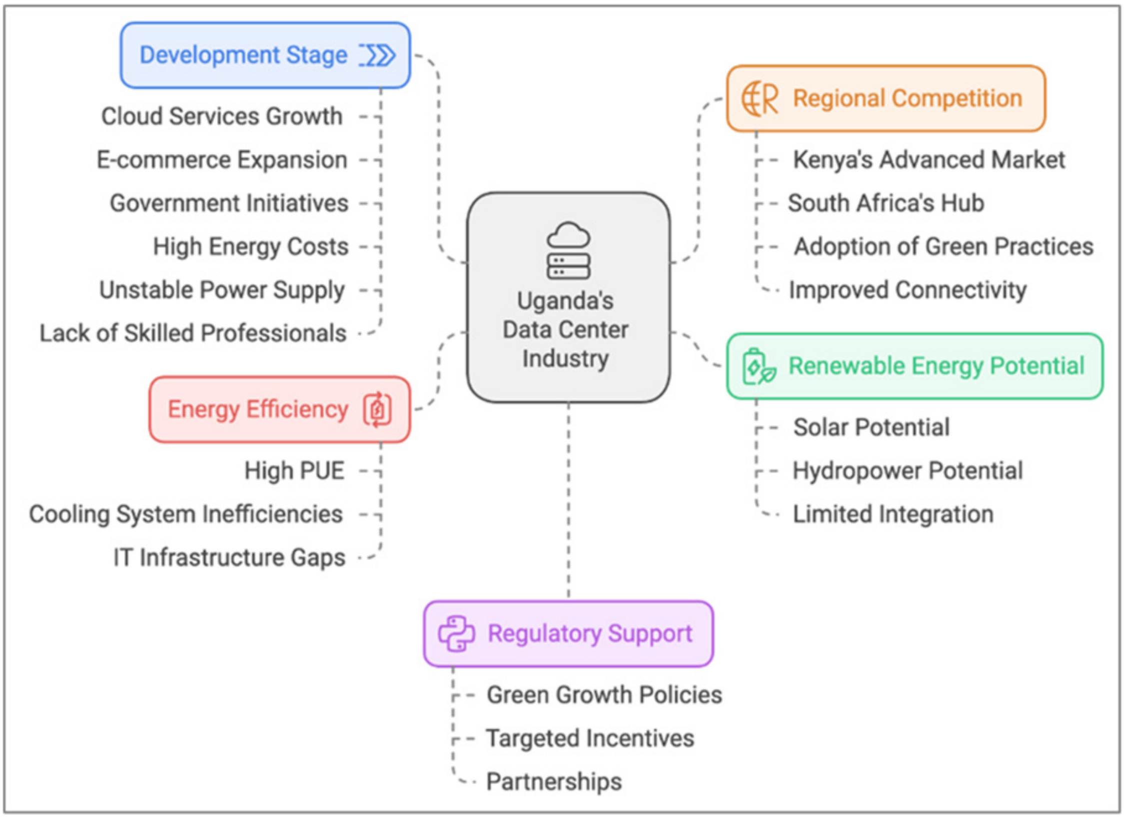
Executive summary

This benchmark report aims to assess Uganda's data centre industry in the context of its digital transformation and increasing demand for colocation and digital services. It compares Uganda's data centres to the best practices set by the relevant international organizations (ITU, AfDB, GSMA, etc.) and with the achievements and progress accomplished in the countries selected as benchmarks for this study, namely, Kenya, South Africa, and France. This benchmark is performed by focusing on key metrics such as energy efficiency, renewable energy usage, data centre security, and overall sustainability.

The goal is to provide a comprehensive analysis that identifies strengths, gaps, and opportunities in Uganda's green data centre development. By aligning with global best practices and examples of benchmarked countries, the report aims to support Uganda's transition to sustainable digital infrastructure.

Key Findings

Figure 7: Key findings in Uganda data centre industry

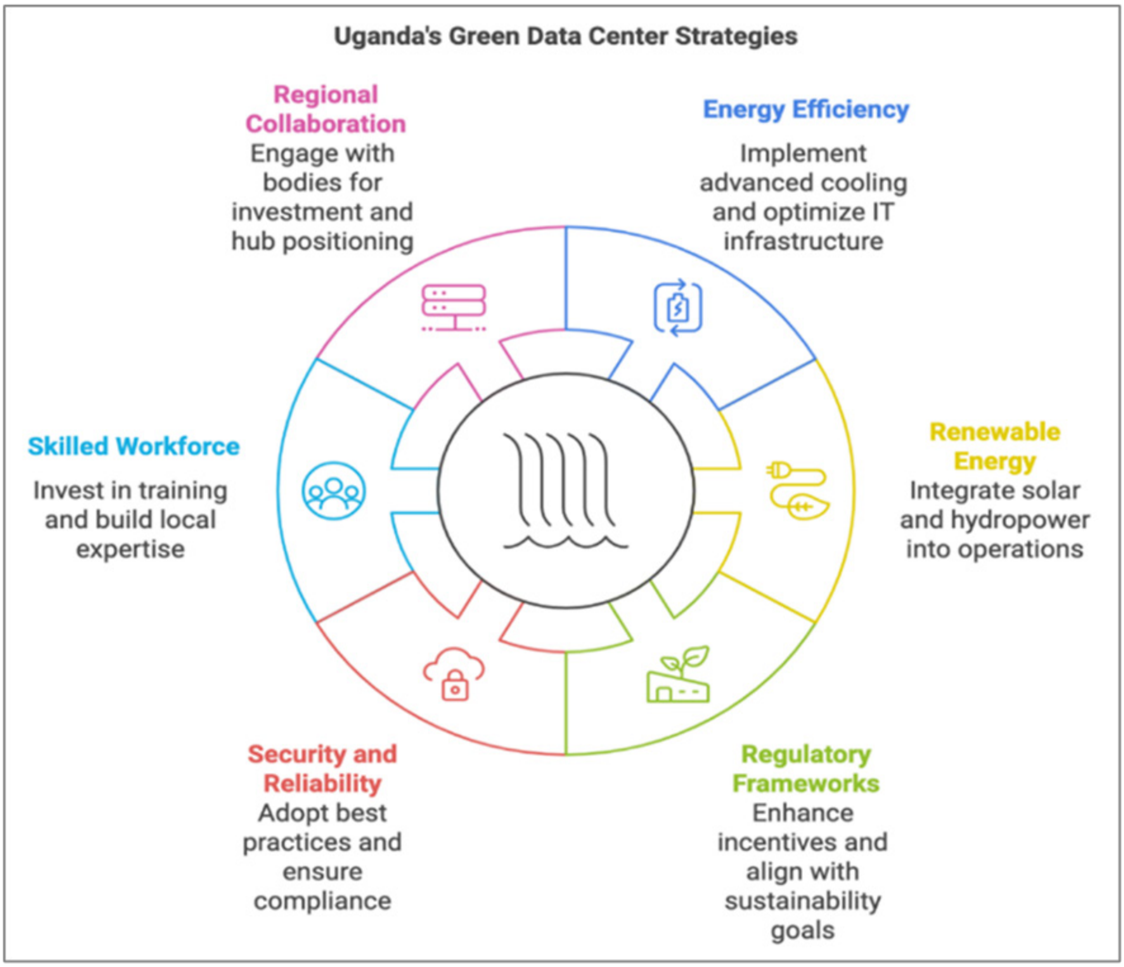


1. **Early stage of development**: Uganda's data centre industry is still in its early stage of development, driven by the growth of colocation, cloud services, e-commerce, and government digital initiatives. The sector faces challenges such as high energy costs, an unstable power supply, and a lack of skilled professionals.

2. **Renewable energy potential**: Uganda has significant renewable energy potential, particularly in solar and hydropower. However, the integration of renewable energy into data centres is still limited.
3. **Energy efficiency gaps**: Uganda's data centres have a higher Power Usage Effectiveness (PUE) compared to benchmarks in Kenya, South Africa, and France. There is a need to adopt more energy-efficient technologies, particularly in cooling systems and IT infrastructure and target a lower PUE.
4. **Regulatory and policy support**: While Uganda has favorable green growth policies under the National Development Plan III, the implementation of those policies remains minimal and there is room for more targeted incentives and partnerships to encourage investment in green data centres.
5. **Competition with regional leaders**: Uganda is competing with more advanced data centre markets in Kenya and South Africa. These countries have established themselves as regional hubs by adopting green practices and improving connectivity, providing a model for Uganda's future development.

Recommendations for Uganda's Green data Centres

Figure 8: Uganda green data centre strategies



1. **Improve energy efficiency**: Focus on reducing the PUE of data centres by implementing advanced cooling systems, optimizing IT infrastructure, and using modular data centre designs. Uganda should target a PUE ratio between 1.4 and 1.8, aligning with the average benchmarks observed in data centres models in Kenya and South Africa.

2. **Leverage renewable energy**: Accelerate the adoption of solar and hydropower in data centres. Uganda's abundant solar potential should be exploited through partnerships with renewable energy providers to integrate clean energy into the operations of facilities like Raxio Data Centre, NITA-U Data centre and others.
3. **Strengthen regulatory and policy frameworks**: Work with the main stakeholders (Ministry of Energy and Mineral Development, Ministry of Information and Communication Technology and National Guidance, Uganda Revenue Authority, National Environmental Management Authority, Electricity Regulatory Authority, Uganda Investment Authority, Ministry of Finance, Planning and Economic Development, Uganda National Bureau of Standards, Uganda Communications Commission, etc.) to enhance incentives for green data centres, such as tax breaks for renewable energy usage and energy-efficient technologies. Align Uganda's data centre strategy with international sustainability goals.
4. **Increase data centre security and reliability**: Adopt international best practices for physical and digital security, ensuring data centres comply with standards like ISO 27001 and offer disaster recovery services to enhance operational continuity.
5. **Develop skilled workforce**: Invest in training programs to build local expertise in data centre management, energy efficiency, and sustainable practices. Partnerships with global firms and organizations like the International Telecommunication Union (ITU), Smart Africa Digital Academy (SADA), etc. can help fill the skills gap.
6. **Promote regional collaboration and investment**: Engage with regional/continental bodies such as EACO (East African Communications Organization) and other international organizations to attract investment in Uganda's green data centres, positioning the country as a regional hub for sustainable digital infrastructure.

Introduction

This benchmark study highlights the crucial role data centres play in Uganda's digital transformation, driven by increasing demand for colocation, e-commerce, digital governance, and cloud-based solutions.

While data centres are essential to managing this digital infrastructure, they also consume significant energy, contributing to higher operational costs and environmental challenges. Without sustainable practices, the energy demands of these data centres could create long-term issues. This study evaluates Uganda's data centre landscape in comparison with global best practices and some selected countries, intending to identify strengths, gaps, and opportunities for improvement.

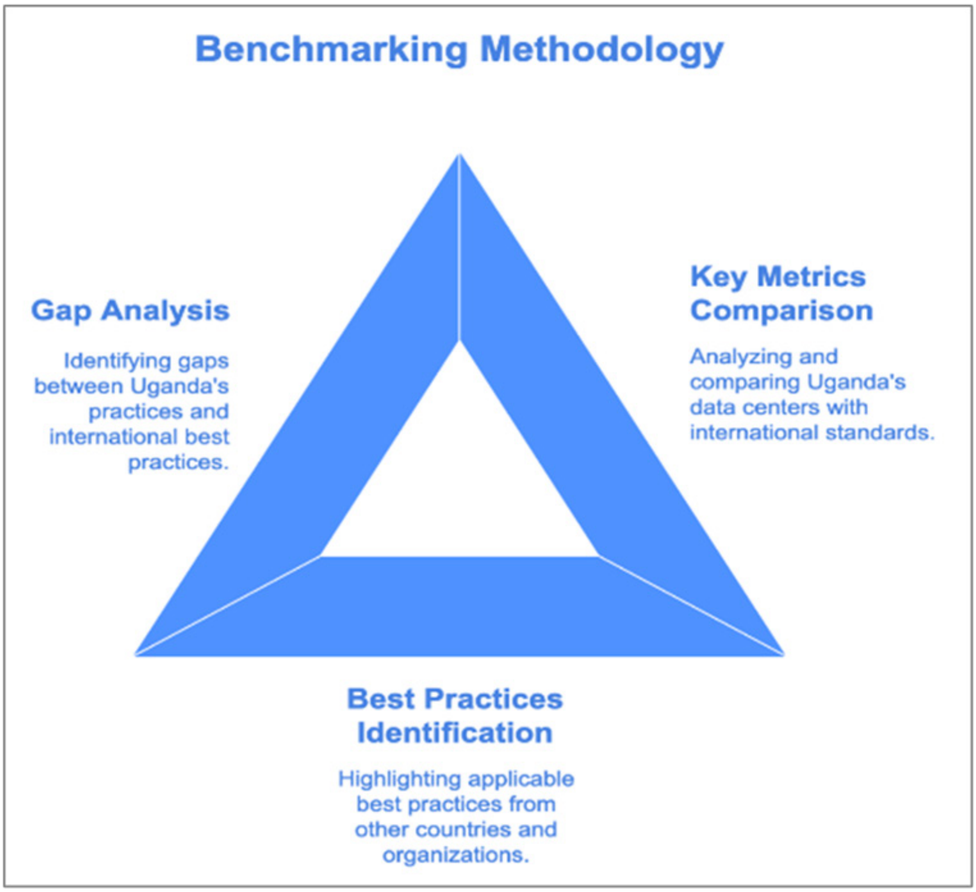
The scope of this benchmark study is comprehensive, considering technical and operational aspects of green data centre efficiency, such as Power Usage Effectiveness (PUE), renewable energy integration, and reliability. Uganda's data centres will be compared to those in countries like Kenya, South Africa, and France, while also referencing international standards set by organizations like the International Telecommunication Union (ITU), GSMA, African Development Bank and others. The study's objectives include assessing Uganda's current performance, identifying areas for improvement, and providing recommendations/guidelines for adopting more energy-efficient and environmentally sustainable practices.

The importance of green data centres in Uganda's context is clearly visible. As the country's digital economy continues to grow, optimizing energy use and reducing carbon emissions are both economic and environmental necessities. Green data centres, which focus on energy efficiency and renewable energy use, will not only reduce operational costs but also support the country's sustainability goals.

Additionally, adopting these practices can improve the reliability of Uganda's digital infrastructure, attract investment, and position the country as a key-player in sustainable digital technologies in the region.

Methodology of the benchmark

Figure 9: Benchmark methodology



a. Selection of benchmarking partners

The first step was to identify countries, organizations, and industry leaders that have demonstrated success in implementing sustainable data centres. These partners have served as the benchmark for Uganda's comparison.

The consortium (APL and Tactis) and the Ministry of ICT and National Guidance team have agreed the following countries for the benchmark: Kenya (CIO Africa, 2023), South Africa (Creamer Media, 2024), France (Cloud Scene, 2024).

Some organizations have been targeted to provide insights: ITU (ITU, 2024), GSMA (GSMA, 2023), AfDB (Africa Development Bank, 2023), and Smart Africa (Smart Africa Secretariat, 2022), GeSI (Glogal e-Sustainability Initiative (GeSI), 2015).

Additional input from previous studies, report, such as those conducted by APL (APL Data Center, 2022) and Tactis (Tactis, 2023) have also provided insights into the benchmarking process.

b. Identification of key metrics

In the list of major key metrics provided by the project team, Uganda Ministry of ICT and National Guidance team selected three + one (3+1) more important metrics, based on their relevance to the efficiency and sustainability of data centres in the context of Uganda.

These metrics are listed below:

Metrics	Description
Power Usage Effectiveness (PUE)	Measures overall energy efficiency by comparing total energy consumption to the energy consumed by IT equipment.
Renewable Energy Usage	The percentage of energy sourced from renewables such as solar or wind power.
Data centre security and reliability	The robustness of the data centre's security measures and its ability to protect data against threats while maintaining operational continuity.
Latency and bandwidth capacity in green data centres	Latency is the time taken for data to travel from one point to another, while bandwidth capacity is the amount of data that can be transmitted in each time.

c. Data collection plan

- **Desktop research**: Secondary data was collected from published reports, white papers, and case studies from the target countries and organizations.
- **Surveys and questionnaires**: Questionnaires have been developed and distributed to key stakeholders in the identified countries and organizations to gather actual and primary data on practices, challenges, and solutions in green data centres. Some local stakeholders in the host country (Uganda) have also responded to the questionnaire: NITA-Uganda, NEMA, UCC, MTN, Ministry of Water and Energy, ICT ministry, Raxio.
- **Interviews**: During the kickoff mission on site, interviews were conducted with experts and stakeholders in Uganda's data centre ecosystem (NITA-U, NEMA, UCC, MTN, Ministry of Water and Energy, ICT ministry, Raxio), as well as from the benchmarking countries to get deeper insights into best practices and innovative solutions.
- **Existing data**: Information and insights obtained during the kickoff mission and the situational and gaps analysis conducted were also leveraged.

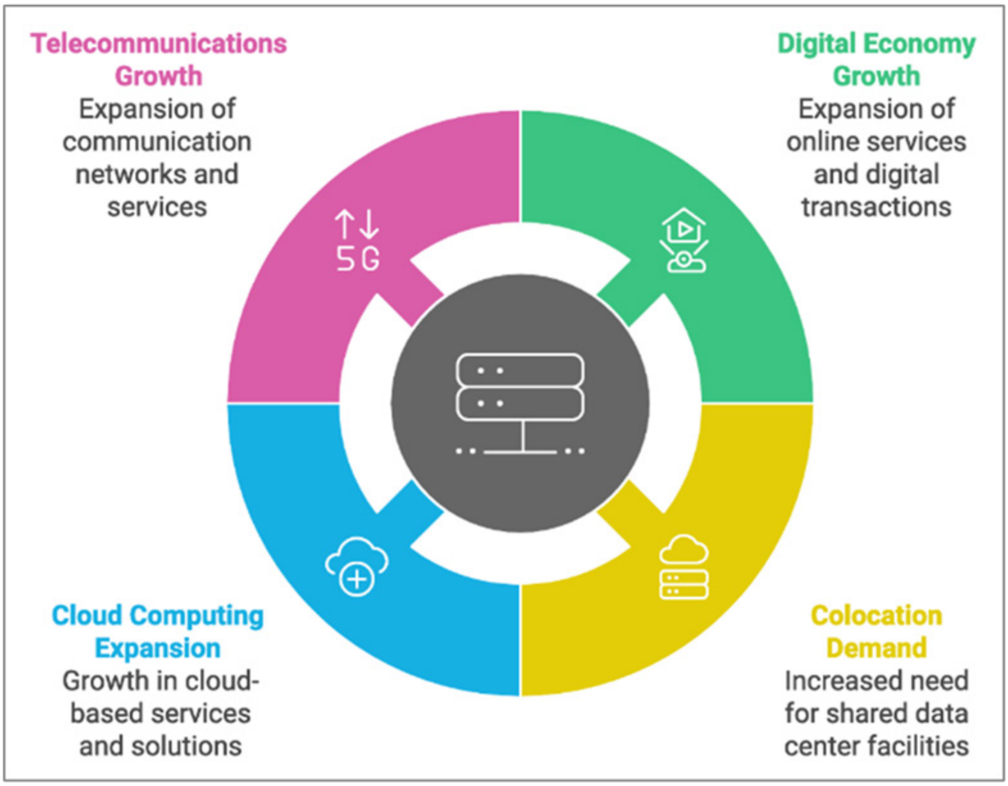
d. Data analysis and synthesis

- **Comparison of key metrics**: The data collected from the benchmarking countries and organizations have been analyzed and compared with Uganda's data centres. Each selected metric has been evaluated to understand where Uganda stands and what needs to be done to reach the desired/expected level.
- **Best practices identification**: From the analysis, best practices from countries like Kenya, South Africa and France, as well as industry standards from organizations like ITU and GSMA, have been highlighted. These practices have been examined in terms of their applicability to Uganda's specific context.
- **Gap analysis**: Gaps have consequently been identified between Uganda's current data centre practices and the international best practices and the benchmarked countries in terms of sustainability, energy efficiency, and operational performance.

Uganda's current situation

1 Uganda data centre market outlook

Figure 10: Uganda data centre market outlook



The visit to Kampala from October 7 to 11, 2024, provided the project team with the opportunity to engage with key stakeholders in digital infrastructure in general and in the data centre sector particularly.

This interaction permitted the team to gain valuable insights into the current landscape of the industry and to formulate well-calibrated recommendations intended at driving significant improvements in Uganda's green data centre ecosystem.

Uganda's data centre market is at an early yet promising stage, driven by the country's growing digital economy, increased demand for colocation, cloud computing, and expanding telecommunications sector.

As the country moves toward more digital services, such as e-commerce, e-government, and financial technology, the need for robust data infrastructure is becoming increasingly critical.

Market drivers

a. Digital transformation

Uganda's digital transformation is accelerating, with a rising demand for colocation, cloud services, data storage, and processing capacity. Key sectors such as banking, telecommunications, and government are rapidly adopting digital solutions, creating a growing need for local data centres.

The increased use of mobile internet (27 per cent of unique users – 13.30 million), the number of active cellular mobile connections in 2024 (33.34 million – 67.7 per cent), the relatively young age of the majority of the population (66 per cent of the population is aged 24 or under), which is a determining factor in data consumption[13] and mobile money services ($104.7 billion in 2023)[14] further drives the demand for scalable data infrastructure.

- **Colocation:** Colocation allows multiple organizations to share data centre resources, cutting costs and environmental impact, aligning with Uganda's ICT policies aimed at reducing the digital divide and fostering sustainability. However, gaps exist in regulatory frameworks, financial support, and awareness, limiting colocation's adoption. Strengthening policies to include incentives for green data centres, establishing clearer standards, and promoting private-public partnerships can address these challenges. By advancing infrastructure sharing and encouraging green practices in data centres, Uganda can achieve both its digital expansion and sustainability goals effectively.
- **Cloud services**: There is growing adoption of cloud solutions by small and medium-sized enterprises (SMEs) in Uganda, which are leveraging the flexibility and cost-effectiveness of cloud-based services. Local data centres are crucial to meet this demand and avoid the latency issues that arise from relying on international data centres.
- **E-government initiatives**[15]: The Ugandan government has launched various e-government services (Uganda Revenue Authority (URA) Online Services, e-Visa System, National Identification and Registration Authority (NIRA), etc.) and the demand for secure, local data hosting is growing. This is also driven by data protection laws that require sensitive government data to be stored locally.

b. Telecommunications expansion

With increasing investments in Uganda's telecommunications infrastructure, including the expansion of the national fiber-optic backbone, the demand for data centres to support telecom services is growing. Telecom operators like MTN Uganda and Airtel Uganda are rapidly expanding their services, and this requires robust data centres for handling traffic, storage, and cloud solutions.

The recent transformation of UTel, the national company in search of investors, will restructure the market from a duopoly position and give consumers a variety of affordable and accessible choices.

- **Mobile penetration**: Uganda has a mobile penetration rate of around 67 per cent, and as more people use smartphones and mobile broadband, the demand for local data hosting services will increase.

c. Rise of financial technology (FinTech)

The FinTech sector in Uganda is growing rapidly, with a focus on mobile money services, digital payments, and online banking. This sector requires highly secure, reliable data centres to handle sensitive financial information, payments, and data storage. As FinTech continues to grow, it will further drive the need for high-performance data centres in Uganda.

13 https://datareportal.com/reports/digital-2024-uganda?rq=Uganda
14 https://www.imarcgroup.com/uganda-mobile-money-market
15 https://www.unapcict.org/sites/default/files/2019-01/Towards%20a%20Model%20for%20Implementing%20Local%20e-government%20in%20Uganda.pdf

d. Data localization and compliance

With growing concerns around data privacy and sovereignty, Uganda has adopted regulations that encourage data localization[16]. This means companies handling sensitive data, particularly in sectors like finance and government, are increasingly required to store data within the country. This trend is expected to drive investments in local data centres to comply with these regulations and reduce the latency emerging with cross-border data hosting.

Key market players

Although Uganda's data centre market is in its early stages, there are some players that are leading the way, including:

A. **Raxio data centre:** Raxio is Uganda's first Tier III carrier-neutral data centre[17], located in Kampala. It is designed to provide a high level of uptime, redundancy, and operational sustainability. Raxio intends to serve not only Uganda but also the broader east Africa region, addressing the demand for colocation, cloud services, and disaster recovery solutions.

Figure 11: Raxio headquarter in Kampala, Uganda (image Raxio Group)

Raxio's Tier III data centre, the first of its kind in Uganda, offers high reliability and minimal downtime, attracting clients from telecommunications, finance, and government sectors. Strategically located in Namanve Industrial Park along key fiber routes, the facility is well-positioned to serve multinational cloud providers seeking reliable local hosting services in Uganda.

B. **MTN Uganda:** MTN Uganda operates six data centres across the country, including major facilities in Mutundwe and Mbuya. These centres house MTN's data servers and facilitate connections for over 15 million customers through 2G, 3G, 4G and 15G networks. The

[16] https://www.engage.hoganlovells.com/knowledgeservices/news/recent-developments-in-african-data-protection-laws-outlook-for-2022_1_1

[17] https://www.intelligentcio.com/africa/2024/08/29/raxio-group-opens-data-centre-with-tier-iii-uptime-certification-in-drc/

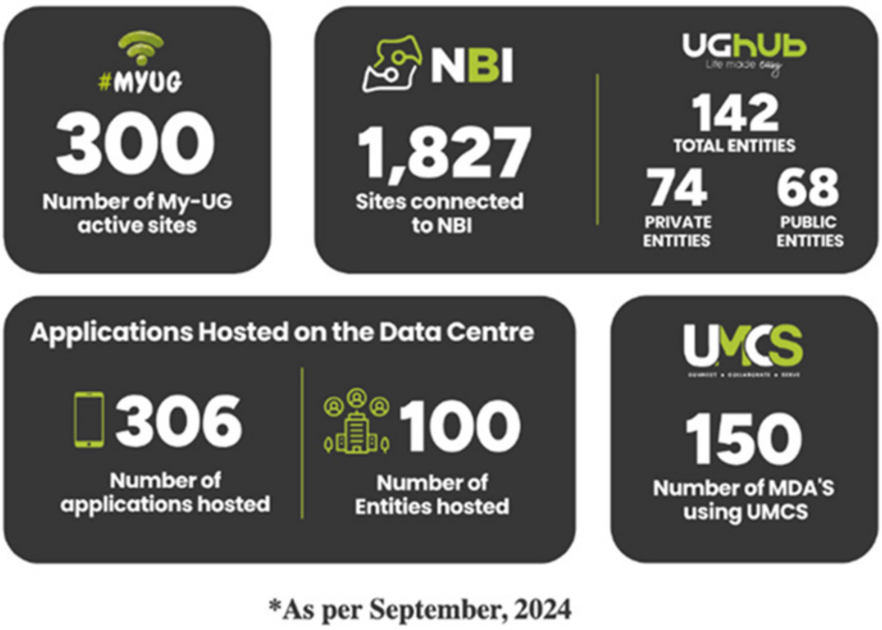
Mutundwe data centre, commissioned in 2012, is a prime facility that supports MN's extensive network infrastructure and is labelled Tier II+ with a trend towards Tier III. [18]

C. **NITA – U:** The NITA-Uganda data centres serve as the foundation of Uganda's digital infrastructure, supporting a wide range of public sector services such as e-government platforms, national databases, and secure communication systems[19].

Designed to international standards, these data centres (labelled Tier II+ with a trend towards Tier III) provide robust colocation, cloud computing, and disaster recovery services, ensuring high availability and security for critical government applications.

Equipped with satisfactory cooling systems, redundant power supplies, and standard physical and cybersecurity measures, NITA-Uganda's data centres are essential to maintaining data integrity and uptime. They are also closely linked to the National Backbone Infrastructure (NBI), which improves national connectivity and internet access, positioning these facilities as key drivers of Uganda's digital transformation by ensuring data sovereignty, promoting digital governance, and improving the overall efficiency of public services.

Figure 12: NITA-U data centres key-numbers



Source: https://www.nita.go.ug/

While other entities like Airtel Uganda, Uganda Telecom (UTL), and various Internet Service Providers (ISPs) maintain data centres or server rooms for data storage, the facilities operated by Raxio, NITA-U, and MTN Uganda represent the largest and most advanced data centres in the country and will be considered for the benchmarking purposes.

18 https://www.mtn.co.ug/mtn-hosts-ict-ministry-for-site-visit-at-mutundwe-data-center/
19 https://www.nita.go.ug/data-center

Investment and Infrastructure

A. National Backbone Infrastructure (NBI)[20]

The Ugandan government's National Backbone Infrastructure (NBI) project is fundamental to improving the country's connectivity.

By expanding fiber-optic coverage across the country, NBI is improving Uganda's data infrastructure and reducing the reliance on expensive and high-latency international links such as microwave and satellite. This is essential for the development of local data centres.

With NBI, Uganda is increasing its bandwidth capacity, making it more attractive for businesses and service providers that require high-speed, low-latency connections.

B. Investment potential

Uganda's data centre market can attract investment from regional and global players. As colocation services and cloud adoption rises and businesses are looking for localized data hosting, there are significant opportunities for both local and international companies to invest in the sector.

While Uganda currently lacks hyperscale data centres, the growing demand for cloud services from major providers like AWS, Microsoft Azure, and Google could lead to investments in hyperscale facilities in the coming years. The regional demand for data hosting and processing makes Uganda a potential target for these large-scale investments.

2 Ongoing green data centres initiatives in Uganda

As Uganda's digital economy grows, the focus on sustainable, energy-efficient data infrastructure is becoming increasingly important. **Uganda is beginning to adopt green data centre practices** intended at improving energy efficiency, reducing carbon emissions, and integrating renewable energy.

Here's an overview of the key initiatives.

A. Raxio data centre – Uganda's first tier III green facility

- **Raxio data centre** is Uganda's first Tier III, carrier-neutral data centre, located in Namanve Industrial Park near Kampala. It was designed with sustainability in mind, focusing on energy efficiency and environmental impact.
- **PUE (Power Usage Effectiveness)**: The facility is designed to achieve a PUE rating of around **1.5**, a significant improvement over traditional data centres, which typically have PUE values between 2.0 and 3.0. This will ensure that energy is used efficiently, with minimal waste. Currently, the facility has a PUE between 1.6 and 1.8.[21]
- **Renewable energy**: Raxio data centre is planning to integrate **solar energy** as part of its energy mix, contributing to reducing its reliance on the national grid and cutting carbon emissions. This reflects Uganda's ambition towards renewable energy adoption, in line with the country's **National Development Plan III**[22].

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20 https://www.nita.go.ug/projects-service-portfolio/national-backbone-infrastructure-project-nbiegi
21 https://www.meridiam.com/assets/raxio-data-centres/
22 https://www.npa.go.ug/wp-content/uploads/2023/03/NDPIII-Finale_Compressed.pdf

B. National Information Technology Authority - Uganda (NITA-U) green initiatives

- **NITA-Uganda** operates two government data centres that are gradually integrating energy-efficient technologies. NITA-U has a long-term goal of improving energy management through the adoption of **renewable energy sources** such as solar power and through optimizing server usage to reduce energy consumption.
- NITA-U's data centres are connected to the **National Backbone Infrastructure (NBI)**, which improves operational efficiency by providing reliable, high-speed connectivity, reducing the need for multiple data centres, and consolidating data processing needs.

C. Renewable energy adoption in Uganda's data centres

Uganda's energy sector relies heavily on renewables, but mainly through traditional bioenergy (firewood and charcoal), which poses environmental and health risks due to deforestation and emissions.

Although 92 per cent of Uganda's energy comes from renewable sources, only 22 per cent of this includes modern renewables, and just 2 per cent contributes to electricity generation. Uganda's energy access remains limited, with only 42 per cent of people having electricity access and a mere 5 per cent with clean cooking solutions.

The Ugandan government, through initiatives like the SEforALL (Sustainable Energy for All) aims to dramatically increase access to electricity, modern cooking options, and improve energy efficiency by 2030. This transformation requires expanding Uganda's renewable energy mix by leveraging its substantial potential in hydro, solar, and other resources, thereby ensuring sustainable energy growth and reducing poverty and environmental degradation[23].

The government's **Third National Development Plan (NDPIII)** targets further integration of **green energy** into industrial and ICT sectors, including data centres, as part of its vision for sustainable development.

[23] https://energytransition.org/2023/09/the-ugandan-energy-sector-renewables-enormous-potential-is-yet-to-deliver/

Case study 1: MTN Uganda's Commitment to Emission Reduction Through Forest Restoration and Decarbonization

Three years ago, MTN Uganda launched an ambitious project aimed at restoring 220 hectares of forest cover as part of the larger "Uganda is Home" campaign. This initiative not only celebrates the partnership between MTN Uganda and the local communities but also reinforces the company's commitment to reducing its environmental impact and enhancing socio-economic development in Uganda.

The forest restoration initiative is a concrete step towards MTN Uganda's goal of achieving net-zero emissions by 2040. Aligned with the 2024 World Environment Day theme of "land restoration, desertification, and drought resilience," this project underscores the critical role that reforestation plays in emission reduction and creating a sustainable future. (MTN Uganda, 2024)

Launched at the Kyewaga Central Forest Reserve in Entebbe and in collaboration with the National Forestry Authority, the project aims to restore forest cover in five Central Forest Reserves (CFRs) across the country, including Barifa CFR in Arua and Kagombe CFR in Kibaale. Each of the 10-hectare restoration sites symbolizes a year of MTN's presence in Uganda, reflecting a long-term commitment to environmental stewardship.

Over the past three years, the initiative has yielded significant benefits. The restored forests not only enhance biodiversity but also support climate regulation, water purification, and soil preservation—all critical factors in reducing emissions and improving local livelihoods.

MTN Uganda's environmental efforts extend beyond reforestation. Through its "Project Zero" initiative, the company has focused on comprehensive decarbonization strategies, resulting in a remarkable 59 per cent reduction in emissions in Q1 2023 compared to Q1 2021. This achievement is largely due to the strategic deployment of smart energy monitoring tools that have provided insights for reducing power consumption.

Additionally, the initiative has successfully targeted Tower Co sites, achieving a 15 per cent reduction in emissions despite the addition of over 1,000 sites within two years. This accomplishment was driven by widespread solar deployments, the integration of lithium-ion batteries, and a strategic shift to more sustainable power sources. (MTN Group, PwC, EY, 2022)

D. Regulatory and policy support for green data centres

a. The **Uganda Green Growth Development Strategy (UGGDS)**[24] supports the adoption of green technologies in ICT infrastructure, including data centres. This policy aligns with Uganda's commitments under the **Paris Agreement**[25] to reduce greenhouse gas emissions.

[24] https://gggi.org/uganda-green-growth-development-strategy-uggds/
[25] https://unfccc.int/process-and-meetings/the-paris-agreement

b. Uganda's **renewable energy policy** promotes the use of clean energy in all sectors, including the IT sector. The government is working to offer incentives, such as tax benefits, for companies investing in renewable energy sources and energy-efficient technologies.

Uganda's green data centre initiatives are still in the early stages, but key players like **Raxio Data Centre, MTN** and **NITA-Uganda** are making significant progress toward adopting sustainable practices.

With a focus on **renewable energy integration**, **cooling efficiency**, and **energy optimization**, Uganda has still a way to developing a data centre ecosystem that aligns with its green growth strategy and international sustainability commitments.

Case study 2: Energy efficiency regulations in France

France's government has enacted policies to improve energy efficiency in data centres. Data centres are required to meet certain standards on power usage effectiveness (PUE) and to disclose energy usage metrics. The "Code of Conduct for Data Centres" by the European Union, adopted widely in France, sets benchmarks for energy use and incentivizes best practices in green energy and efficiency. (European Commission, 2022)

3 Challenges and opportunities

Challenges

a. Energy supply and costs

One of the primary challenges for green data centre growth in Uganda is the **unreliable energy supply** and high electricity costs. Data centres require continuous, stable electricity, and Uganda still faces frequent outages and inconsistencies in power supply. Solutions such as **solar energy** and backup generators are necessary, but these increase operational costs.

b. Limited skilled workforce

Building and operating data centres require specialized skills in areas such as IT infrastructure management, cooling systems, and energy efficiency. Uganda currently faces a shortage of skilled professionals in these areas, which could slow down the development of the data centre market and green data centre particularly. Investing in training programs and partnerships with global firms will be key to addressing this gap.

c. Competition from regional hubs

Uganda is competing with established regional hubs like **Kenya** and **South Africa**, which have more advanced data infrastructure, greater access to renewable energy, and better connectivity to international undersea cables. Uganda will need to differentiate itself through targeted investments in green technologies, local data hosting requirements, and improving cross-border fiber connectivity.

d. Uganda unique Internet Exchange Point (IXP)

Another challenge is Uganda's reliance on a single Internet Exchange Point (IXP). Data centres require robust interconnection to the internet, and a single IXP limits competition, creates a single point of failure, and restricts network diversity. Expanding IXP infrastructure would enhance resilience, improve connectivity options, and foster a more competitive environment for data exchange (D. Ó Briain, D. Denieffe, Y. Kavanagh and D. Okello, 2017).

Opportunities

a. Cloud services and colocation

As Uganda's economy is going towards digital, the need for **cloud services** and **colocation** facilities is growing. Data centres like Raxio are benefiting and will benefit from businesses looking for cost-effective, local hosting solutions that can reduce latency and improve service delivery.

b. Attracting global cloud providers

Uganda's growing demand for digital services and its strategic location in East Africa provide for the country an opportunity for **global cloud providers** to set up local points of presence (PoPs). Investment in reliable and scalable data centres will position Uganda as a viable location for **AWS**, **Microsoft Azure**, or **Google Cloud** to establish local infrastructure, which would help accelerate the country's digital growth.

Moreover, favourable regulations and progressive policies are crucial in promoting a diverse range of investments in Uganda's green data centre sector, extending beyond major cloud providers and over-the-top (OTT) players.

By implementing clear guidelines and attractive incentives—such as tax benefits for green technology adoption, reduced energy tariffs for renewable-powered data centres, and streamlined licensing processes—the Ugandan government can significantly lower entry barriers for a variety of investors, including smaller technology firms, telecommunications operators, and local entrepreneurs.

Additionally, policies that encourage infrastructure sharing can help reduce the initial capital requirements for data centre deployment. This approach enables different organizations to co-locate and share resources, making data centre investments more accessible and economically feasible for a broader range of stakeholders.

c. Edge computing and 5G rollout

The **5G rollout** in Uganda is opening new opportunities for data centres, particularly in **edge computing**.

Edge data centres, which bring data storage and computing closer to the user, will be critical for delivering real-time services such as IoT, smart city initiatives, and low-latency applications. Uganda's telecom companies (MTN, Airtel and Utel) will require local data centres to support 5G-enabled services, opening a new avenue for data centre investments.

d. Uganda location

Uganda's geographical location offers significant opportunities for developing green data centres, particularly due to its abundant renewable energy resources, such as hydroelectric power from the Nile River and potential for solar energy.

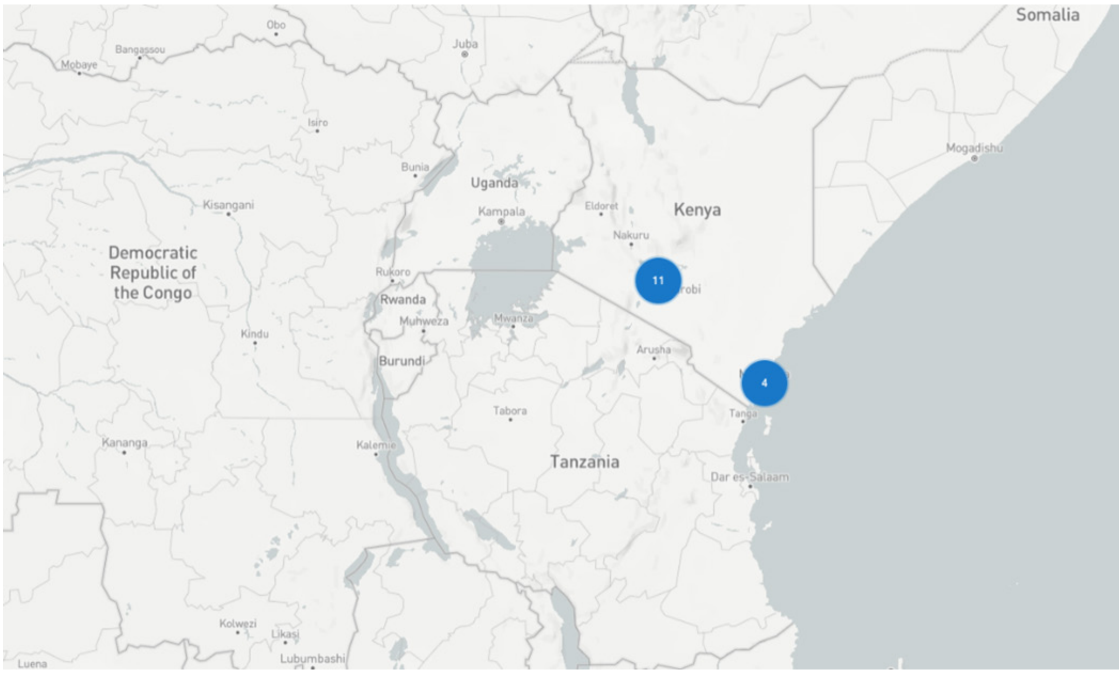
Located in East Africa, Uganda's central position makes it an ideal regional data hub, capable of serving neighbouring countries and reducing latency for East and Central African users.

The country's moderate climate, with relatively cool temperatures in elevated areas, could also lower cooling costs, further reducing energy demands for data centres.

These factors create a foundation for sustainable and efficient data centre operations, positioning Uganda as a key player in Africa's digital and green economy.

Benchmarking Country 1: Kenya Data Centre Industry

Figure 13: Kenya Data Centres Map (https://www.datacentremap.com/)



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Kenya data centre map indicates that the country has currently **15 data centres** spread across two main cities, Nairobi (11) and Mombasa (4).

Kenya's data centre industry has been growing rapidly in response to the increasing demand for digital infrastructure, cloud services, and internet connectivity across the country. This growth is largely driven by the expansion of the financial services sector, mobile telecommunications, e-commerce, and government digitization efforts.

Figure14: Kenya major data centres players

1 Data centres market outlook

The Kenya data centre market is expecting to receive investments of USD 440 million by 2029, growing at a CAGR of 11.66 per cent from 2024-2029[26]. The government of Kenya launched the National Optic Fiber Backbone Infrastructure (NOFBI) to create a secure and digital highway for business applications and Value-Added Services (VAS). This infrastructure expansion increased international traffic, reduced internet costs, and improved internet speeds. Also, collaborative efforts between the government and private sectors ambition to position Kenya as a technology hub in the region, driven by proactive measures.

The government of Kenya introduced a 10-year Information Communication Technology (ICT) master plan (2022-2032)[27] to boost its technology and digital economy. This plan focuses on four main areas: improving digital infrastructure, enhancing digital services and data management, building digital skills, and promoting digital innovation for entrepreneurship. It is a roadmap to keep Kenya on track with global technology trends.

The Kenya data centre market is growing rapidly due to better internet connections, the growing use of smartphones, the constant growth in internet users, and the growing number of internet-connected devices across the market. Additionally, Kenya anticipates a significant economic boost by implementing 5G, particularly in the agriculture, healthcare, and education sectors. The country is focused on developing supportive policies regulations and making substantial investments to maximize these benefits. The growing 5G environment will further drive the demand for edge data centres in the coming years.

a. Major data centre providers

Provider	Description
IXAfrica	In 2022, IXAfrica, a data centre operator, announced plans to build East Africa's largest hyperscale data centre in Nairobi, with an initial capacity of 4.5 MW, which can be scaled up to 42.5 MW.
Liquid Intelligent Technologies	Formerly known as Liquid Telecom, Liquid Intelligent Technologies operates multiple data centres across Kenya, offering cloud services, colocation, and managed services. Their East Africa Data Centre (EADC) is one of the region's largest facilities.

[26] https://www.arizton.com/market-reports/kenya-data-center-market-investment-analysis
[27] https://cms.icta.go.ke/sites/default/files/2022-04/Kenya%20Digital%20Masterplan%202022-2032%20Online%20Version.pdf

(continued)

Provider	Description
PAIX Data Centres	Another key player, PAIX operates carrier-neutral data centres in Nairobi, with plans to expand further. Their Nairobi campus provides a range of services including colocation, interconnectivity, and cloud solutions
Safaricom	The telecommunications giant Safaricom, which controls much of Kenya's mobile data market, has built its own data centres to support its expanding services, including mobile banking and cloud services

b. Connectivity and fiber infrastructure

High-speed Internet: Kenya has a robust fiber-optic backbone, with several submarine cables landing at Mombasa, including the Eastern Africa Submarine Cable System (EASSy), The East African Marine System (TEAMS), Meta 2Africa, and SEACOM. This makes the country an ideal location for data centres serving both the local market and neighboring countries.

Internet penetration: As of 2024, Kenya had an internet penetration rate of 41 per cent, with mobile broadband being the primary mode of internet access. This increasing connectivity is boosting demand for data storage, cloud services, and other digital infrastructure.[28]

c. Government initiatives and regulatory framework

Konza Technopolis: Kenya's government is actively promoting digital infrastructure through initiatives like Konza Technopolis, a smart city under development that is designed to attract technology companies and serve as a regional hub for ICT services, including data centres.[29]

Regulatory framework: The government has implemented policies and regulations to support data centre growth. The Communications Authority of Kenya (CA)[30] oversees the ICT sector and promotes a favorable regulatory environment for private sector investment in data infrastructure.

Data Protection Act (2019)[31]: Kenya's Data Protection Act, which aligns with international best practices, mandates data localization and privacy protection, indirectly promoting the need for local data centres to manage and store information securely within the country.

d. Investment and Public-Private Partnerships

Private sector investment: Major tech firms, including Microsoft and Google, have been increasing their presence in Kenya. In 2022, Microsoft launched its first African Development Centre in Nairobi[32], which will rely on local data centres for cloud services and infrastructure support.

Public-Private Partnerships: The government has encouraged partnerships between public institutions and private data centre operators. For instance, the National ICT Master Plan highlights the role of data centres as part of Kenya's vision to become a regional ICT hub.

28 https://datareportal.com/reports/digital-2024-kenya
29 https://konza.go.ke/
30 https://www.ca.go.ke/
31 https://www.kentrade.go.ke/wp-content/uploads/2022/09/Data-Protection-Act-1.pdf
32 https://www.capitalfm.co.ke/business/2022/03/microsoft-opens-africa-development-centre-facility-in-nairobi/

Case Study 3: Africa Data centre (ADC) in Nairobi

Africa Data Centres (ADC) in Nairobi is a notable case study showcasing Kenya's advancements in sustainable green data centre infrastructure. Leveraging Kenya's abundant renewable energy resources, the ADC facility in Nairobi operates largely on green power sources, such as geothermal, hydro, and wind, which supply over 75 per cent of Kenya's electricity grid. This reliance on clean energy significantly reduces the data centre's carbon footprint, making it one of the greenest facilities in Africa. Additionally, Kenya's government supports renewable energy and digital infrastructure growth through policies like the Kenya National Broadband Strategy and Vision 2030, which provide regulatory clarity and incentives for green technology investments. These initiatives create an attractive environment for data centres by lowering costs and encouraging eco-friendly practices.

Furthermore, ADC has implemented energy-efficient cooling systems, such as free-air cooling, capitalizing on Kenya's moderate climate to reduce energy use and costs associated with cooling. The development of ADC's Nairobi data centres also benefited from public-private partnerships, as Kenya encourages collaboration with private entities to enhance infrastructure investment and technological innovation. Tax exemptions and subsidies on renewable components further incentivize green infrastructure, attracting both local and international investors. (Africa Data Center, 2023)

2 Green initiatives in the data centres

Kenya's focus on sustainable development, linked with its status as a leading hub for digital infrastructure in East Africa, has stimulated the growth of **green data centres** that prioritize energy efficiency and environmental sustainability.

Green data centres reduce their carbon footprint by optimizing energy usage, integrating renewable energy sources, and implementing environmentally friendly operational practices.

Below are the key insights about **green data centres** in Kenya:

a. Renewable energy utilization

- **Energy mix**: Kenya's electricity grid is powered predominantly by renewable energy, with about **90 per cent of the country's energy coming from renewable sources**. The country is a leader in geothermal energy production, contributing around **47 per cent of the energy** in the national grid, alongside other sources like hydroelectric, wind, and solar power.[33]
- **Data centres commissioning renewable energy**: Data centres in Kenya, particularly in Nairobi, are increasingly sourcing electricity from this renewable energy grid. This reliance on green energy positions Kenyan data centres as some of the most sustainable in Africa.[34]

[33] https://ourworldindata.org/energy/country/kenya
[34] https://www.eib.org/en/essays/kenya-renewable-energy-transport-innovation

b. Power Usage Effectiveness (PUE)

- **PUE Ratios**: Power Usage Effectiveness (PUE) is a key metric in measuring the energy efficiency of data centres. Leading green data centres in Kenya, such as those operated by **Liquid Intelligent Technologies** and **IXAfrica**, have achieved PUE ratios between **1.4 and 1.6** in the last years. This indicates relatively efficient energy usage, where a lower PUE reflects less energy wasted on cooling and infrastructure.[35]

Case study 4: Achieving a PUE of 1.4 at Liquid Intelligent Technologies' Data Centres in Kenya[36]

Overview: Liquid Intelligent Technologies has attained an impressive PUE of 1.4 in its Kenyan data centres, which reflects highly efficient energy usage—indicating that only 40 per cent of power beyond the IT equipment load is used for cooling, lighting, and other facility needs. This efficiency level is one of the lowest in Africa, signifying a major step toward sustainability and operational cost-effectiveness.

Levers of success:

Utilization of Kenya's renewable energy resources: Liquid Intelligent Technologies leverages Kenya's renewable energy-rich grid, particularly geothermal, hydro, and wind power, which supplies over 75 per cent of the country's electricity. Access to this stable, clean power reduces both operational costs and carbon emissions, enabling more sustainable energy consumption.

Innovative cooling solutions: The data centre employs advanced cooling techniques like **free-air cooling**, which uses outside air when temperatures are favourable to cool the facility without relying heavily on traditional air conditioning. Kenya's moderate climate, especially in elevated areas, enables this strategy to be highly effective, significantly reducing cooling energy requirements and contributing to a lower PUE.

Energy-efficient design and equipment: The facility is designed with energy-efficient infrastructure, including **high-efficiency uninterruptible power supplies (UPS)**, **modular power systems**, and **LED lighting**. By optimizing these systems, Liquid Intelligent Technologies minimizes power waste and enhances overall energy efficiency.

[35] http://africadca.org/wp-content/uploads/2022/05

[36] https://www.iea-4e.org/wp-content/uploads/2024/02/Policy-development-on-energy-efficiency-of-data-centres-draft-final-report-v1.05.pdf

Real-time monitoring and management systems: Liquid Intelligent Technologies employs advanced **energy management and monitoring systems** to continually assess and adjust power usage in real-time. This enables quick identification of inefficiencies and helps ensure that cooling, lighting, and equipment operations are optimized to maintain the PUE at a low level.

Proactive maintenance and infrastructure upgrades: Regular maintenance and timely upgrades of equipment, including cooling and power systems, prevent energy inefficiencies from developing over time. Liquid Intelligent Technologies uses data from monitoring systems to inform maintenance schedules, ensuring sustained energy efficiency and reliability.

Impact and lessons: This achievement demonstrates that with the right mix of renewable energy access, climate-appropriate cooling, and efficient infrastructure, data centres in Africa can operate sustainably and achieve low PUE ratings. Liquid Intelligent Technologies' approach shows how energy efficiency can be maximized in alignment with Kenya's renewable resources and moderate climate, setting a benchmark for future data centres in the region. Country like Uganda looking to develop green data centres can replicate this model by investing in efficient design, leveraging local renewable resources, and implementing proactive monitoring and maintenance practices. (Fiona Bloklehurst, Ballarat Consulting, 2024)

c. Government support and sustainability goals[37]

- **Kenya Vision 2030**: The government of Kenya has committed to sustainability goals as part of its **Vision 2030** strategy, which emphasizes the need for sustainable infrastructure, including green data centres. The promotion of green energy in Kenya has created a supporting environment for the development of data centres that prioritize renewable energy.
- **Data localization and green growth**: Kenya's **Data Protection Act** mandates data localization for certain types of data, driving the need for more local data centres. The push for green data centres aligns with this by ensuring that as local storage demand grows, the environmental impact is minimized.

d. Cooling efficiency and innovations

- **Natural cooling**: Kenyan data centres benefit from Nairobi's high altitude, which provides cooler ambient temperatures. This reduces the energy needed for cooling systems, a significant factor in improving the overall energy efficiency of data centres.
- **Airflow and HVAC systems**: Many of the green data centres in Kenya have implemented advanced **HVAC (heating, ventilation, and air conditioning)** systems, reducing the power needed for cooling and maintaining optimal temperatures for IT equipment. These systems are designed to use less water and energy, further contributing to green operations.

[37] https://www.treasury.go.ke/wp-content/uploads/2023

e. Data centre infrastructure investments

- **Increased investment in green facilities**: Kenya is seeing growing interest from both local and international investors in green data centre infrastructure. In addition to IXAfrica and Liquid Intelligent Technologies, other operators such as Safaricom, Equinix, East African Data Centre (EADC), etc. are exploring opportunities to build energy-efficient, sustainable data centres to meet the demands of Kenya's expanding digital economy.[38]

f. Carbon footprint reduction

- **Geothermal and wind energy integration**: Data centres in Kenya have a significant advantage in terms of reducing their carbon footprint due to the country's investments in **geothermal and wind energy projects**. The **Lake Turkana Wind Power Project**[39] and extensive geothermal plants in **Olkaria** are two major contributors to Kenya's renewable energy grid. By tapping into these sources, data centres can significantly reduce their reliance on non-renewable energy and lower greenhouse gas emissions.

Figure 15: Lake Turkana Wind Farm (www.soisolutions.com)

- **Reduced diesel generator use**: Due to the reliability of renewable energy in Kenya, data centres are less reliant on diesel generators for backup power, further reducing their carbon emissions.

g. Public-private partnerships for green growth

- **Collaborative initiatives**: Kenya's government, through various public-private partnerships, is working with data centre operators to promote sustainability. For example, the development of **Konza Technopolis**[40], a smart city designed to house green data centres, emphasizes eco-friendly technologies and renewable energy integration.

[38] https://www.theeastafrican.co.ke/tea/sustainability/kenya-bags-75m-eu-grant-for-green-investments-4414016
[39] https://ltwp.co.ke/
[40] https://konza.go.ke/

3 Challenges and opportunities

Challenges

a. **High energy costs**: Despite a strong renewable energy mix, the cost of electricity in Kenya can still be high, which presents a challenge for data centre operators struggling to improve efficiency and maintain competitiveness in the region.

Figure 16: Historic electricity cost data in Kenya (https://www.stimatracker.com/historic)

	Average electricity cost (KES/kWh)																	
Period	DL	DL2	DC	SC1	SC2	CI1		CI2		CI3		CI4		CI5		CI6		IT
					Peak	Off-peak	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak		
Sep 2024	20.29	25.50	28.57	20.29	28.96	22.11	13.80	20.54	13.01	19.91	12.70	19.62	12.55	19.28	12.38	17.59	14.47	28.57
Aug 2024	20.48	25.70	28.77	20.48	29.16	22.31	14.00	20.74	13.21	20.11	12.90	19.82	12.75	19.48	12.58	17.79	14.66	28.77
Jul 2024	20.03	25.24	28.32	20.03	28.70	21.86	13.54	20.28	12.76	19.65	12.44	19.36	12.30	19.02	12.13	17.33	14.21	28.32
Jun 2024	21.16	26.41	31.25	21.16	30.55	23.90	15.13	22.18	14.27	21.50	13.93	21.19	13.77	20.85	13.60	18.45	15.33	31.25
May 2024	20.29	25.54	30.38	20.29	29.68	23.03	14.25	21.31	13.40	20.63	13.06	20.32	12.90	19.98	12.73	17.58	14.46	30.38
Apr 2024	20.98	26.23	31.07	20.98	30.37	23.71	14.94	21.99	14.08	21.31	13.74	21.00	13.58	20.66	13.41	18.27	15.14	31.07
Mar 2024	23.14	28.39	33.23	23.14	32.53	25.87	17.10	24.15	16.24	23.48	15.90	23.16	15.74	22.82	15.58	20.43	17.31	33.23
Feb 2024	23.25	28.51	33.35	23.25	32.64	25.99	17.22	24.27	16.36	23.59	16.02	23.28	15.86	22.94	15.69	20.54	17.42	33.35
Jan 2024	26.72	31.97	36.81	26.72	36.11	29.46	20.68	27.74	19.82	27.06	19.49	26.75	19.33	26.41	19.16	24.01	20.89	36.81

b. **Water usage for cooling**: Although many data centres are optimizing cooling systems, water usage remains a concern. Some facilities have had to implement more efficient water management systems to prevent wastage in cooling processes.

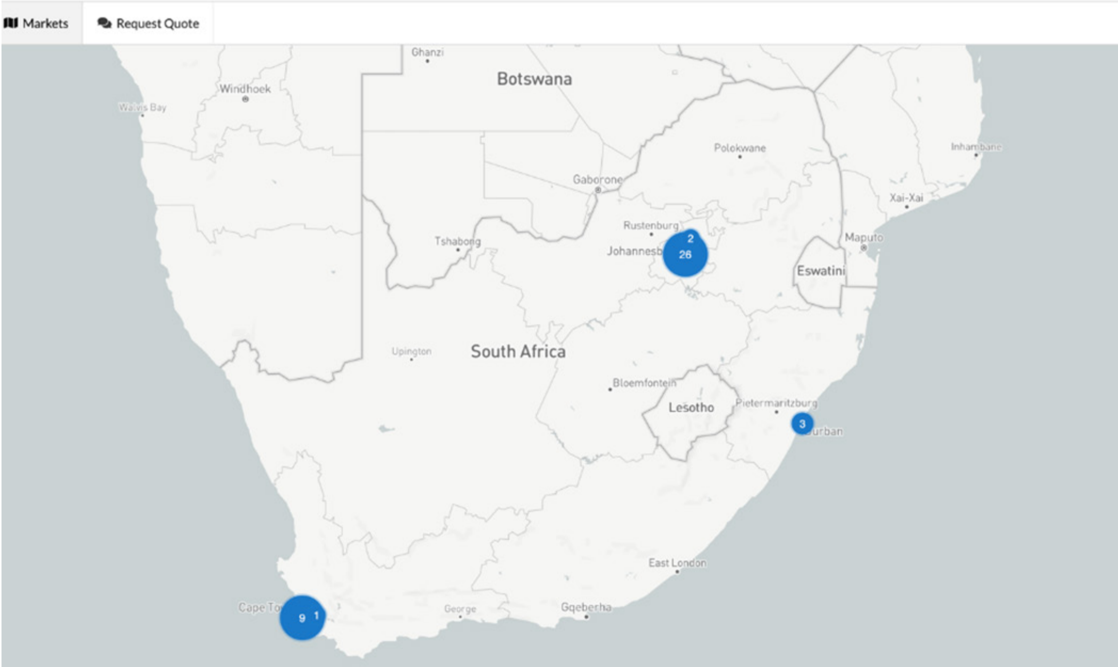
Opportunities

a. **Expansion into renewable energy:** Kenya's rich renewable energy resources present a unique opportunity for the data centre industry to expand sustainably. Additional investment in solar and wind energy, combined with innovations in energy storage, could improve the green qualifications of Kenyan data centres.

b. **Regional leadership**: With its focus on green data centres, Kenya is well-positioned to lead the east Africa region in sustainable digital infrastructure. This could attract more investment from global tech giants seeking eco-friendly data centre solutions in Africa.

Benchmarking country 2: South Africa Data Centre Industry

Figure 17: South Africa data Centre map (www.datacentremap.com)



The designations employed and presentation of material in this publication, including maps, do not imply the expression of any opinion whatsoever on the part of ITU concerning the legal status of any country, territory, city or area, or concerning the delimitations of its frontiers or boundaries.

South Africa data centre map indicates that the country has currently **41 data centres** spread across two big markets, Johannesburg (26), Cape Town (9) and three small markets Durban (3), Pretoria (2) et Stellenbosch (1).

The South African data centre industry is experiencing rapid growth, driven by increasing demand for cloud services, colocation, digital transformation, and a growing need for local data hosting due to data sovereignty laws like the **Protection of Personal Information Act (POPIA).**[41]

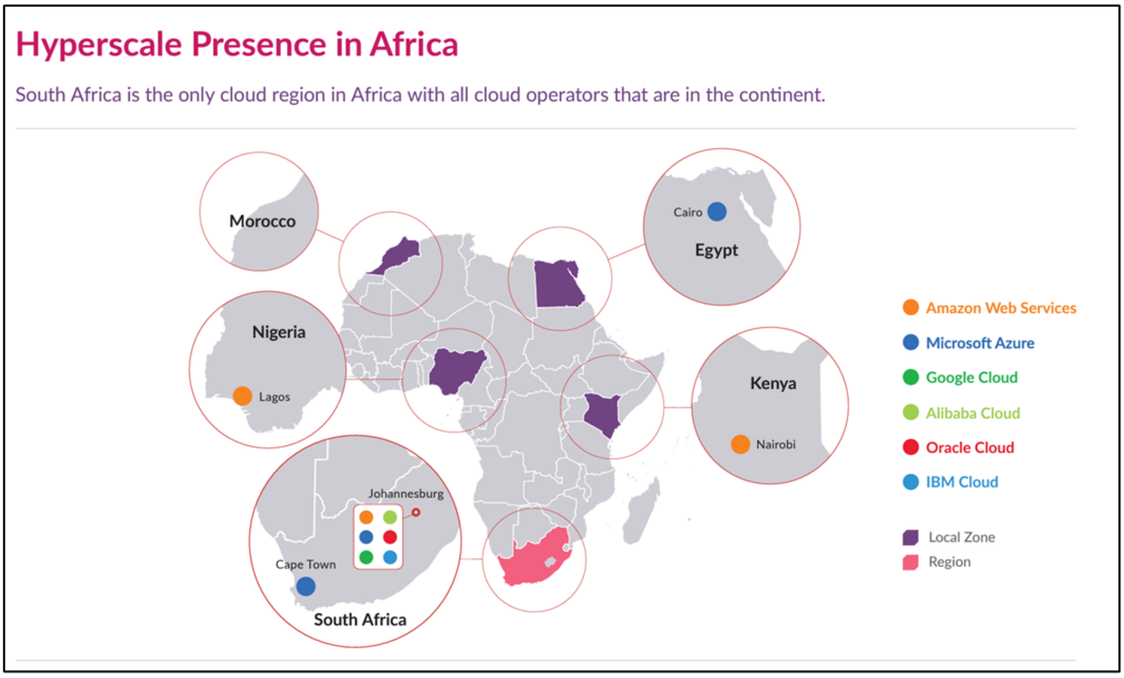
Major global cloud providers such as AWS, Microsoft Azure, and Google Cloud have established local infrastructure, while local companies are expanding their data centre capacities to meet both domestic and regional needs across Sub-Saharan Africa. Johannesburg and Cape Town are key data centre hubs due to their robust IT infrastructure, power availability, and connectivity to undersea cables, while emerging markets like Durban are also seeing investment.

This growth is further powered by the expansion of sectors like fintech, e-commerce, and remote work, making South Africa a critical player in the continent's digital landscape.

41 https://popia.co.za/

Figure 18: Major DC players in South Africa (www.mordorintelligence.com)

Figure 19: Hyperscale presence in Africa (South Africa) (www.pica-publishing.com)



1 Data centre market outlook

The data centre market in South Africa is on a rapid growth trend, powered by increasing demand for cloud services, digital transformation, and the rise of data sovereignty requirements.

a. Key facts and figures

- The South African data centre market is expected to grow at a **compound annual growth rate (CAGR) of 4.67 per cent** between 2024 and 2029, resulting in a market volume of USD 1.52 bn in 2029. [42]

[42] https://www.statista.com/outlook/tmo/data-center/south-africa

b. Key players and investments

- **Amazon Web Services (AWS)** launched its first cloud data centres in Cape Town in 2020, providing local data hosting and cloud solutions to meet data residency requirements.
- **Microsoft Azure** has two data centre regions in South Africa—one in Johannesburg and another in Cape Town—becoming the first global provider to open data centres in Africa in 2019.
- **Google Cloud** is also investing in the region, with plans to establish a cloud region in South Africa by 2024.

c. Power consumption

- South Africa's data centres consume an immense amount of power, estimated at 652.29 MW—equivalent to over 15,655 MWh daily—which could potentially power around 2.2 million homes. The market value of these centres stands at R8.6 billion and is projected to grow to R20.2 billion by 2029. Operating 24/7, data centres demand significant cooling, effectively doubling their IT power load. In response to frequent electricity supply issues from Eskom, some providers, like Teraco, are investing in sustainable power sources, including a 120 MW solar plant. National policies emphasize reducing grid dependency, urging data centres to secure their own water and electricity sources, especially as government incentives may support these initiatives. Environmental regulations also require centres to avoid sensitive locations, maintain resilience with 99.995 per cent uptime for government-used facilities, and uphold certifications to assure operational standards.[43]
- Data centres face significant challenges due to **load shedding** (scheduled power outages) in South Africa, increasing the need for backup power infrastructure and renewable energy sources such as solar and wind.[44]

d. Connectivity and infrastructure

- South Africa's data centre growth is supported by excellent connectivity to international undersea cables, including **ACE (Africa Coast to Europe)**, **WACS (West Africa Cable System)**, and **SAT-3**. This provides robust international bandwidth and makes South Africa a key hub for data processing and storage in Sub-Saharan Africa.
- Johannesburg is the primary data centre hub due to its position as a business centre and its superior connectivity, but **Cape Town** and **Durban** are growing markets for data centre expansions.

e. Market Drivers

- **Cloud services**: The increasing adoption of cloud-based services by businesses across sectors is a primary driver of demand for local data centres. By 2027, cloud adoption is expected to account for a significant portion of the data centre industry's revenue.
- **Data sovereignty**: The implementation of the **Protection of Personal Information Act (POPIA)** requires companies to host data within South Africa, further accelerating the demand for local data centre infrastructure.
- **5G Rollout**: The deployment of **5G** in South Africa will boost the demand for edge computing and real-time data processing, which will drive further investments in local data centres.

[43] https://mybroadband.co.za/news/cloud-hosting/542397-south-africas-data-centres-could-power-2-9-million-homes.html

[44] https://techcentral.co.za/data-centres-south-africa-energy-crisis/239869/

2 Green initiatives in the data centres

Green initiatives in data centres in South Africa, are gaining significant adhesion as environmental concerns and sustainability goals become more obvious. South Africa's unique challenges—such as power supply constraints, heavy reliance on coal, and growing data demands—make green initiatives in the data centre sector particularly critical.

Here are some notable green initiatives and trends observed in South Africa's data centres:

a. Renewable energy integration

- **Solar power**: Given South Africa's abundant sunlight, many data centres are exploring or implementing solar energy to reduce their reliance on the national grid. For instance, companies are increasingly building solar farms to power their data centres or supplement energy needs.[45]

  Wind energy: Some data centres have begun using wind power in addition to solar, especially in regions where wind energy potential is high.[46]

b. Energy-efficient infrastructure

- **Efficient cooling systems**: Cooling is one of the biggest power-consuming aspects of data centres. South African data centres are adopting technologies such as free cooling (using outdoor air) and liquid cooling systems to reduce the energy required for cooling servers.[47]
- **Smart data centres**: There is a shift towards smart technologies and automation to monitor and optimize energy consumption. By using sensors, AI, and IoT technologies, data centres can automatically adjust power and cooling needs in real-time to minimize waste.[48]
- **Energy management systems (EMS)**: Implementation of EMS helps data centres continuously monitor energy use and optimize it by reducing consumption where possible.

c. Sustainable building designs

- **Green building certifications**: Data centres in South Africa are pursuing certifications like Green Star SA, which evaluates sustainability factors in building design, materials, water management, and more. LEED certifications (Leadership in Energy and Environmental Design) are also being adopted in some cases.
- **Modular and prefabricated data centres**: Modular data centre designs allow for scalable growth, which helps optimize energy use. Prefabricated centres can be built with higher efficiency and sustainability in mind from the beginning.

d. Carbon reduction programs[49]

- **Carbon offsetting**: Some South African data centres have started to implement carbon offsetting programs to compensate for their emissions by investing in local or global environmental projects.

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45 https://www.africadatacentres.com/africa-data-centres-and-dpa-sa-breaks-ground-on-solar-farm-in-free-state/

46 https://www.engineeringnews.co.za/article/sas-data-hub-future-clean-energy-is-non-negotiable-2024-05-24

47 https://refrigerationandaircon.co.za/optimising-cooling-of-data-centres/

48 https://www.itweb.co.za/article/microsoft-in-30bn-partnership-to-build-ai-data-centres/G98YdMLGQ1W7X2PD

49 https://www.sanews.gov.za/south-africa/south-africa-aims-zero-emissions-2050

- **Reducing reliance on coal**: The South African energy grid is heavily dependent on coal, which poses a significant environmental challenge. Data centres are therefore exploring alternative energy sources and carbon-reduction technologies to reduce reliance on coal-based power.

e. Sustainable water usage (Jack Olley, Marin Cvitanovic, Tilak Ginige and Laura Bunt-MacRury, 2024)

- **Water efficiency**: In response to water shortage issues, data centres are focusing on water-efficient cooling systems. Some are moving towards air-cooled data centres, reducing water usage significantly. In addition, many facilities are investing in systems that reuse and recycle water, lowering their water footprint.
- **Rainwater harvesting**: Data centres are incorporating rainwater harvesting systems to meet some of their non-potable water needs, further reducing stress on municipal water supplies.

f. Partnerships and collaboration

- **Public-private partnerships**: To scale sustainability, many data centres collaborate with government and non-government organizations to improve energy efficiency standards and invest in renewable energy sources.
- **Industry collaboration**: The data centre industry is seeing increased collaboration in South Africa to promote best practices for sustainability, such as through the creation of joint energy policies, sustainability forums, and data-sharing on green technologies.

g. Local grid support and off-grid solutions

- **Microgrids**: Due to frequent load shedding and power disruptions in South Africa, data centres are developing microgrids to maintain stable power while incorporating renewable energy. Microgrids can operate independently from the national grid and often use a combination of solar, wind, and battery storage.
- **Battery storage solutions**: Some data centres are deploying large-scale battery storage to store renewable energy and reduce their dependence on the grid, especially during peak demand periods or outages.

h. E-waste management

- **Sustainable IT hardware disposal**: Data centres are increasingly focusing on proper e-waste disposal, recycling, and reusing IT hardware. This initiative includes donating decommissioned equipment, refurbishing servers, and responsibly recycling outdated hardware to reduce the environmental impact of e-waste.

i. Government policies and incentives

- The South African government has been working on policies and frameworks to encourage sustainable energy usage and emissions reduction. These policies may include tax incentives for companies adopting green technologies and renewable energy in their data centres.
- The government's push for renewable energy projects (such as the Renewable Energy Independent Power Producer Procurement Program, REIPPPP)[50] helps facilitate the

[50] https://ndcpartnership.org/knowledge-portal/good-practice-database/south-africas-renewable-energy-independent-power-producer-procurement-programme

integration of renewables into the grid, which benefits energy-intensive industries like data centres.

Green initiatives in South African data centres are evolving in response to the challenges of energy shortages, environmental concerns, and global pressure to reduce carbon footprints. These efforts are helping drive a transition toward more sustainable operations, which is essential not only for reducing environmental impact but also for ensuring business resilience and energy security in the future.

The combination of technological innovation, government policy support, and industry collaboration is key to accelerating this transformation in the country.

3 Challenges and opportunities

Green data centres in South Africa present a unique mix of challenges and opportunities due to the country's economic, energy, and environmental landscape. The adoption of sustainable practices in the data centre sector is essential to align with global trends in reducing carbon footprints, but South Africa faces hurdles such as energy instability and high costs of renewable energy adoption.

Here's a breakdown of the **challenges and opportunities** associated with green data centres in South Africa, supported by examples, facts, and numbers.

Challenges

a. Energy supply instability (load shedding)[51]

- **Issue**: South Africa has been dealing with energy shortages and regular power outages due to its old energy infrastructure and reliance on coal. Eskom, the national utility, frequently implements "load shedding" to manage power demand, which severely impacts the uptime of data centres and can influence the OPEX of the data centres.
- **Impact**: Data centres are energy-intensive, and the frequent interruptions from load shedding require substantial investment in backup power solutions, **such as diesel generators, which counteract green efforts.**

b. Dependence on coal for electricity[52]

- **Issue**: South Africa's energy grid is heavily dependent on coal-fired power plants, with approximately **80 per cent of the country's electricity generated from coal**. This reliance declines green efforts as data centres are dependent on a carbon-intensive energy grid.
- **Impact**: Without large-scale renewable energy adoption at a national level, the green data centre movement faces limitations in achieving low carbon footprints, especially when on-grid energy is still coal-dependent.
- **Fact**: South Africa's **coal dependency contributes around 45 per cent of the country's carbon emissions**, making it one of the highest carbon emitters per capita in the world.

[51] https://ratedpower.com/blog/south-africa-energy-crisis/
[52] https://www.trade.gov/country-commercial-guides/south-africa-energy

c. Water scarcity

- **Issue**: South Africa is a water-scarce country, and data centres traditionally use large amounts of water for cooling systems. Sustainable water management is critical but often expensive, requiring investment in water-efficient cooling technologies or air-based cooling systems.
- **Fact**: According to the **World Resources Institute**[53], South Africa ranks as a country with **high water stress**, making water usage in data centres a critical environmental concern.

d. High costs of renewable energy adoption

- **Issue**: Building renewable energy infrastructure—such as solar or wind farms—requires significant upfront investment, which can be a barrier, especially for smaller data centre operators. Additionally, renewable energy solutions, like battery storage, are expensive and may have long payback periods.
- **Fact**: According to **South Africa's Integrated Resource Plan (IRP) 2019**[54], the country aims to reduce coal's share of energy production to **59 per cent by 2030**, replacing it with more renewables. However, the transition is slow and costly for sectors like data centres.

e. Lack of incentives and policy framework

- **Issue**: While South Africa is making steps towards renewable energy, the regulatory framework for incentivizing green data centres, such as tax breaks or rebates for renewable energy investment, is still developing.
- **Impact**: The slow development of policy frameworks can discourage large-scale investments in green data centre technology.
- **Fact**: South Africa's **Renewable Energy Independent Power Producer Procurement Program (REIPPPP)** has facilitated renewable energy projects but does not yet provide substantial incentives targeted at specific industries like data centres.

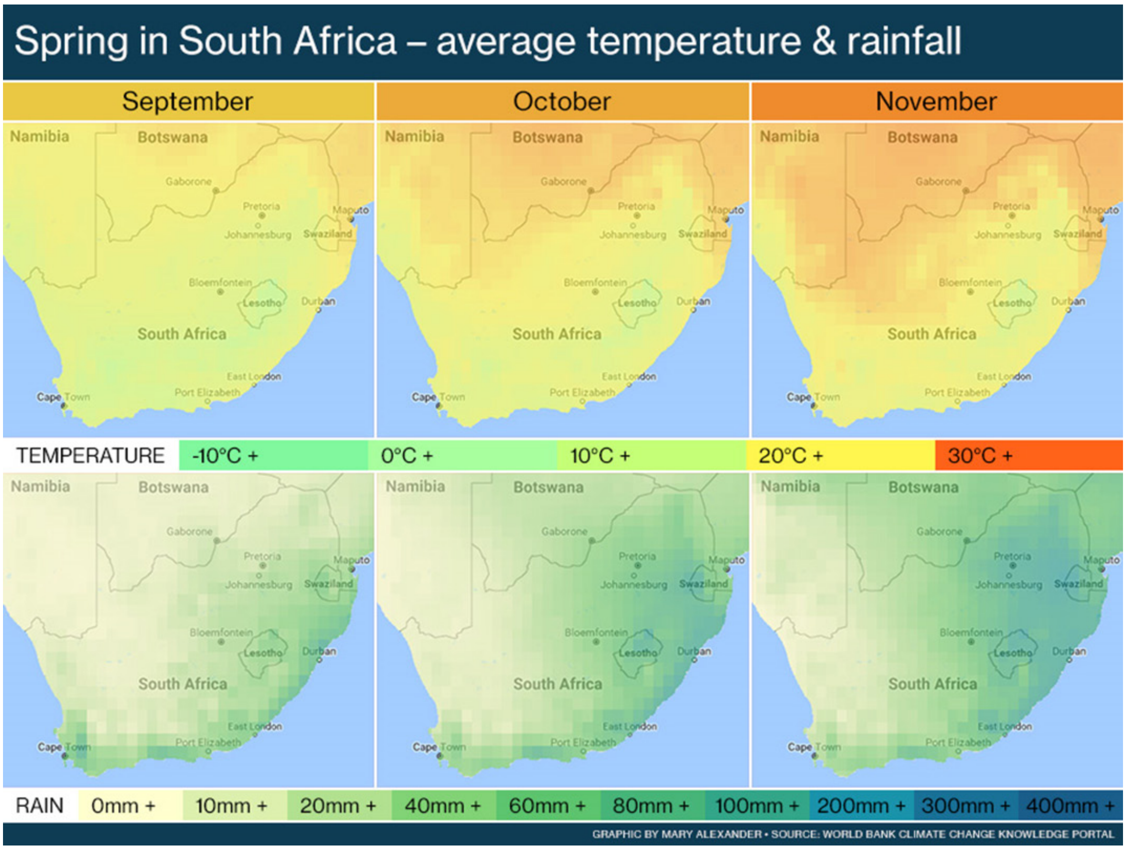
Opportunities

a. Abundant renewable energy potential

- **Opportunity**: South Africa has excellent potential for solar and wind energy. Solar radioactivity in South Africa is among the highest in the world, making solar energy a promising option for data centres.
- **Fact**: The country receives **2,500 hours of sunshine per year**[55], making it ideal for solar farms to power green data centres. By 2030, South Africa aims to generate **20 GW of electricity** from renewables.

53 https://www.wri.org/update/south-african-cities-show-commitment-accelerate-water-resilience-2023-un-water-conference
54 https://www.cliffedekkerhofmeyr.com/news/publications/2019/Corporate/energy-alert-22-october-The-Integrated-Resource-Plan-2019-A-promising-future-roadmap-for-generation-capacity-in-South-Africa.html
55 https://southafrica-info.com/land/south-africa-weather-climate/

Figure 20: Average temperature in South Africa (Image: South Africa Gateway)



b. Reduction of operational costs through energy efficiency

- **Opportunity**: Green data centres, which incorporate energy-efficient designs, often see a significant reduction in operational costs over the long term. Technologies such as free cooling, which uses outside air, and advanced monitoring systems can cut down energy usage and costs.
- **Fact**: Data centres can reduce energy consumption by up to **40 per cent** using advanced cooling technologies and automation (according to reports from **Uptime Institute**[56]).

c. Demand for colocation and cloud services

- **Opportunity**: The rise in demand for cloud computing, colocation, and edge computing services in South Africa is creating opportunities for data centres that integrate sustainable practices. Green data centres are particularly attractive to environmentally conscious businesses. The African data centre market, driven by South Africa, is expected to grow at a compound annual growth rate (CAGR) of **12 per cent** from 2021 to 2026[57], making sustainability a key differentiator for data centre providers.

d. Government support for renewable energy

- **Opportunity**: While still in its beginning, the South African government is increasingly focused on promoting renewable energy adoption. The **REIPPPP** has already awarded contracts for large renewable energy projects, which can potentially supply green energy to the data centre industry.

56 https://intelligence.uptimeinstitute.com/resource/efficient-servers-hold-key-energy-efficient-data-centers
57 https://www.arizton.com/market-reports/africa-data-center-market

- **Fact**: South Africa's REIPPPP has attracted over **R209 billion** in private sector investment and contributed significantly to the renewable energy grid (by early 2021). This could expand to supply green power to energy-hungry sectors like data centres.

e. New green technologies

- **Opportunity**: Data centres in South Africa can adopt innovative green technologies such as AI-based energy management, energy-efficient server hardware, and battery storage solutions. These innovations reduce carbon footprints and improve overall efficiency.
- **Fact**: Global data centres are expected to invest **$90 billion** in green technologies by 2030, with South Africa expected to contribute to this trend.

f. Global pressure and ESG (Environmental, Social, Governance) reporting

- **Opportunity**: There is increasing pressure on companies to report their environmental impact through ESG reporting. South African data centres that have adopted green initiatives are positioned themselves as leaders in sustainability, attracting more international clients.
- **Fact**: According to the **International Finance Corporation (IFC)**, energy-efficient data centres can reduce their energy use by up to **50 per cent,** making them attractive for ESG-focused investors and clients.[58]

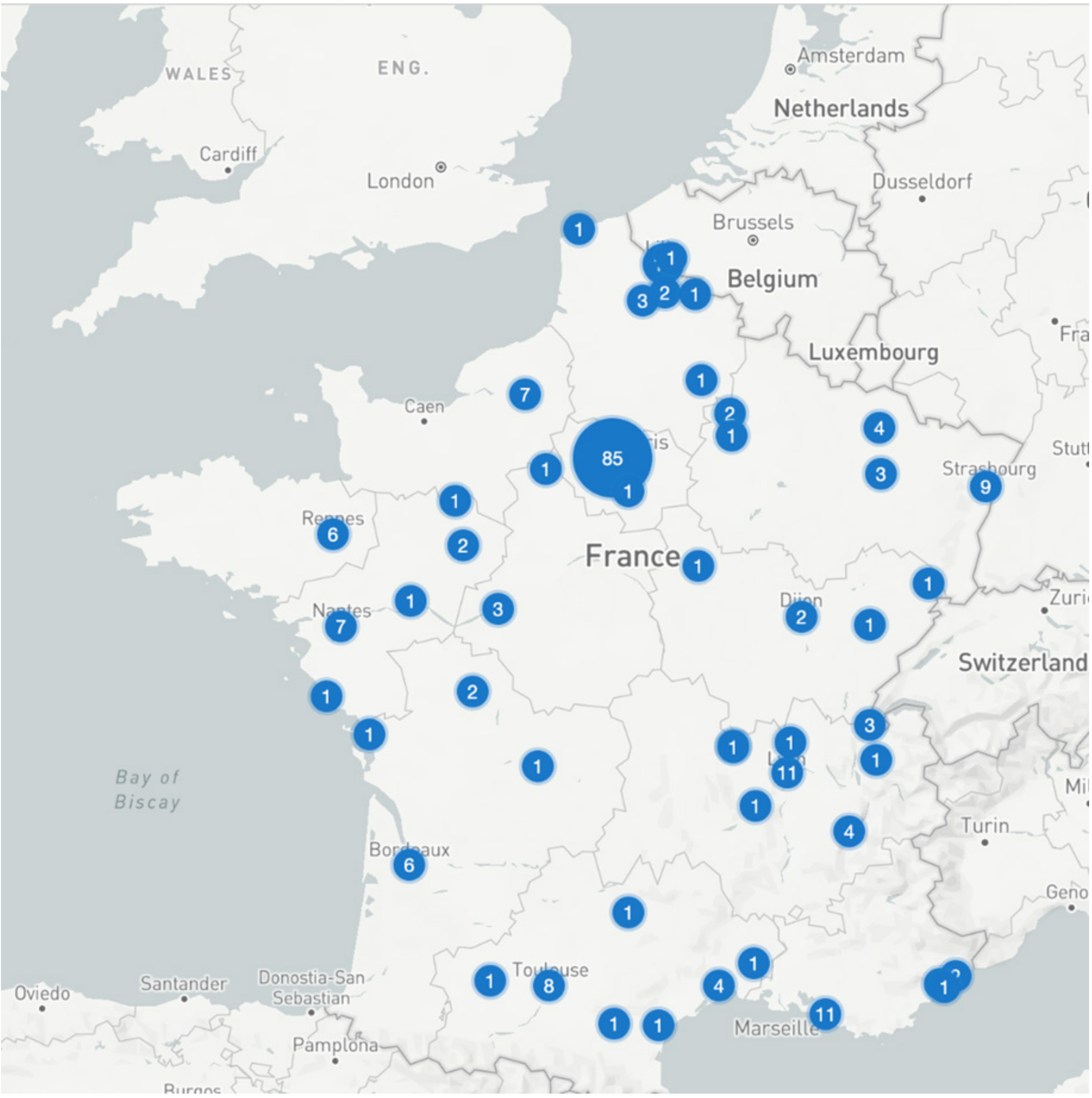
While South Africa faces significant challenges, such as a defective power grid, coal dependency, and high costs of renewable energy infrastructure, the country also has immense opportunities in green data centres.

The abundance of solar energy, government programs promoting renewable energy, and the growing demand for environmentally friendly services present exciting reasons for data centre operators to follow sustainability. Those that have successfully integrated green technologies stand to benefit from reduced operational costs, increased customer demand, and regulatory incentives.

[58] https://www.ifc.org/content/dam/ifc/doc/mgrt/59988-ifc-greenbuildings-report-final-1-30-20.pdf

Benchmarking country 3: France Data Centre Industry

Figure 21: France data centre map (https://www.datacentremap.com/)



France data centre map indicates that the country has currently **236 data centres** spread across four big markets, Paris (85), Lyon (11), Marseille (11) and Lille (19) and some small markets, Strasbourg (9), Toulouse (8) et Rouen (7).

The French data centre market is composed for substantial growth, with projections indicating a compound annual growth rate (CAGR) of approximately 4.93 per cent from 2022 to 2027, reaching a market size of around USD 4 billion by 2027 (Arizton, 2022)[59]. This growth is driven by the rapid adoption of cloud computing, artificial intelligence, and big data analytics, as well as the increased demand for digital services across industries.

France's strategic location in Western Europe, along with its robust IT infrastructure and energy grid, has attracted major cloud service providers such as AWS, Microsoft Azure, and Google Cloud, all of whom have established data centre regions in the country.

59 https://www.arizton.com/market-reports/france-data-center-market-report-2025

Additionally, French companies like OVHcloud and Scaleway are expanding their facilities to meet local and international demand. The country's data centre market is also benefiting from government support for digital transformation, including the France Relance Plan, which allocates €7 billion[60] to digital technologies, part of which supports the development of data centres.

Sustainability is a significant focus in France's data centre market. France positions among the top countries in Europe for renewable energy use, with nearly 20 per cent of its electricity coming from renewable sources in 2021, primarily hydroelectric power (RTE, 2021).[61]

This emphasis on green energy aligns with the European Union's Green Deal, which targets carbon neutrality by 2050.

Data centre operators in France are increasingly adopting energy-efficient practices, such as using advanced cooling technologies and renewable energy to reduce their carbon footprint.

For example, OVHcloud has implemented water-cooling technology to improve energy efficiency. Additionally, regulatory trends like the EU's GDPR and concerns over data sovereignty are driving demand for local data centres, with companies seeking to ensure compliance with data privacy laws by hosting their data within France's borders. Top of Form

Bottom of Form

1 Data centre market outlook

The data centre market in France is growing rapidly, driven by the increasing adoption of cloud computing, artificial intelligence, IoT, and big data technologies. By 2027, the French data centre market is expected to reach around **USD 4 billion**, growing at a **CAGR of approximately 6 per cent** from **2022 to 2027**[62].

This expansion is supported by a flow in demand for digital services, the growing need for edge computing, and the rollout of 5G networks. France's central location within Europe, robust connectivity infrastructure, and relatively low latency make it an attractive destination for both global cloud providers and regional players.

A. Key players and investments[63]

a. **Global cloud providers**:

- **Amazon Web Services (AWS)**, **Microsoft Azure**, and **Google Cloud** have all invested heavily in France, establishing dedicated cloud regions and data centres to serve both local and European customers. AWS opened its Paris region in 2017, while Microsoft Azure and Google Cloud have similarly expanded their footprints to capitalize on the growing demand for cloud services in Europe.

60 https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/ang_synthese_france_relance_decembre_2022.pdf
61 https://assets.rte-france.com/analyse-et-donnees/2023-08/Bilan%20%C3%A9lectrique%202022%20rapport%20GB_version_finale%20(2).pdf
62 https://www.arizton.com/market-reports/france-data-center-market-report-2025
63 https://www.mordorintelligence.com/industry-reports/france-data-center-market#

b. **French cloud providers**:

- **OVHcloud**, one of the largest cloud service providers in Europe, is a key player in the French data centre market. The company operates **33 data centres worldwide**, with significant capacity in France. OVHcloud is known for its focus on sustainability, using water-cooling technologies and renewable energy to power its facilities.
- **Scaleway** is another notable French provider that is expanding its operations. It has several data centres in the Paris region and is focused on providing colocation and cloud services tailored to small and medium-sized enterprises (SMEs).

c. **Colocation and hyperscale operators**:

- **Equinix** and **Digital Realty** are major international colocation providers with significant investments in France. Equinix operates multiple International Business Exchange (IBX) data centres in the **Paris** and **Bordeaux** regions, while Digital Realty has expanded its colocation services to meet the growing demand for hyperscale facilities.
- **Data4**, a European colocation leader, operates a large campus near Paris, offering capacity for hyperscale, colocation, and cloud services. Data4 has plans to invest more in expanding its campus to support the growing demand for data centre space.

B. Investment Trends

The French government is actively supporting digital infrastructure development as part of its broader **France Relance** recovery plan, which includes investments in digital transformation, cloud services, and 5G deployment. In addition, France's relatively low energy costs, access to renewable energy, and focus on sustainability make it a favourable destination for data centre investments.

Private investment in the sector is also increasing, with data centre operators focusing on expanding capacity and improving energy efficiency.

For example, **OVHcloud** recently raised significant capital through its IPO in 2021, signalling its ambition to continue expanding both domestically and across Europe.

Edge data centres are also gaining traction, with companies investing in smaller, decentralized facilities to support real-time applications and 5G networks.

These trends, combined with the regulatory environment (e.g., **GDPR**), which promotes data sovereignty, made France one of the key data centre hubs in Europe.

2 Green initiatives in the data centres

France is leading the way in the adoption of green initiatives within its data centre industry, driven by both regulatory pressures and corporate sustainability goals.

With growing energy demands from digital services such as cloud computing, AI, and big data, data centres have become significant consumers of energy. As a result, there is a strong push toward energy efficiency and sustainability. The focus on green initiatives is aligned with the European Union's **Green Deal**[64], which aims for carbon neutrality by **2050**, and France's **Energy Transition Law**[65], which sets ambitious targets for renewable energy and reduced carbon emissions.

64 https://www.consilium.europa.eu/en/policies/green-deal
65 https://www.ecologie.gouv.fr/sites/default/files/documents

Key green initiatives

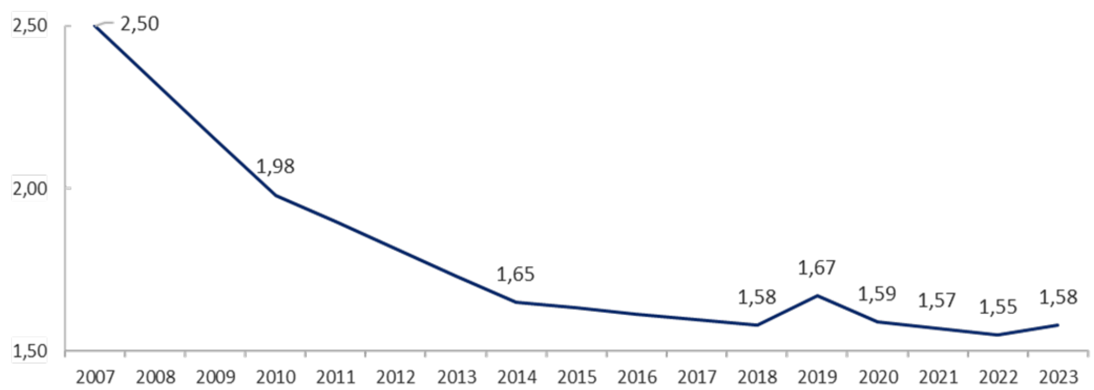
a. **Renewable Energy Usage**:

- In 2021, around **20 per cent** of France's electricity came from renewable sources, particularly **hydroelectric power**, with significant contributions from wind and solar energy (RTE, 2021)[66]. This access to renewable energy helps data centre operators reduce their carbon footprints by sourcing electricity from low-carbon sources.
- Some operators, like **OVHcloud**, have committed to using 100 per cent renewable energy in their data centres, leveraging France's extensive hydropower resources. In **2022**, OVHcloud reported a **carbon intensity of less than 0.20 kg CO2 per kilowatt-hour**, making it one of the leaders in sustainable energy use in the European data centre market[67].

b. **Energy efficiency and cooling technologies**:

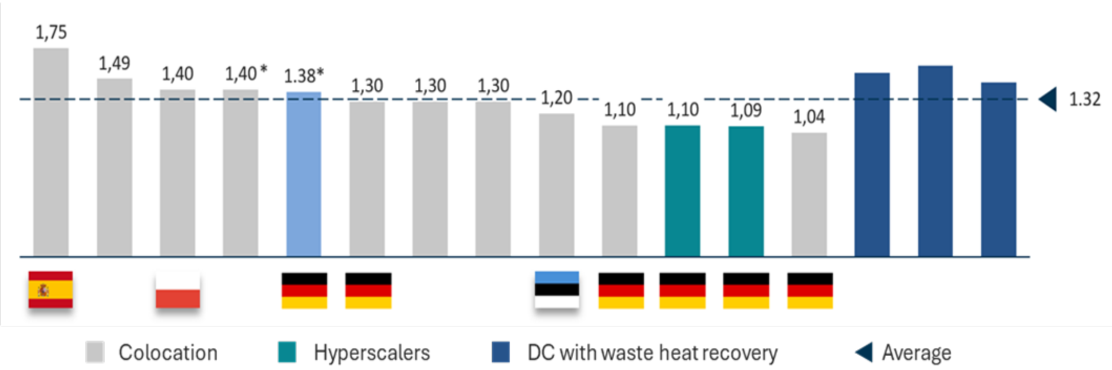
- French data centres are increasingly adopting innovative cooling technologies to improve energy efficiency. **OVHcloud** has implemented water-cooling technology across its facilities, which reduces electricity consumption by cooling servers more efficiently than traditional air-cooling methods. OVHcloud's water-cooling systems use about **30 per cent less energy** compared to standard cooling systems, contributing to lower **Power Usage Effectiveness (PUE)**.
- Many data centres in France have achieved PUE ratings of **1.2 or lower**, significantly reducing energy wastage. For instance, the **Data4 Group**, which operates a large data centre campus near Paris, is focused on achieving a PUE of **1.2** through efficient cooling and energy management practices.

Figure 22: Evolution of the average annual PUE, worldwide



66 https://analysesetdonnees.rte-france.com/en/electricity-review-keyfindings
67 https://corporate.ovhcloud.com/en/newsroom/news/carbon-calculator-launch/

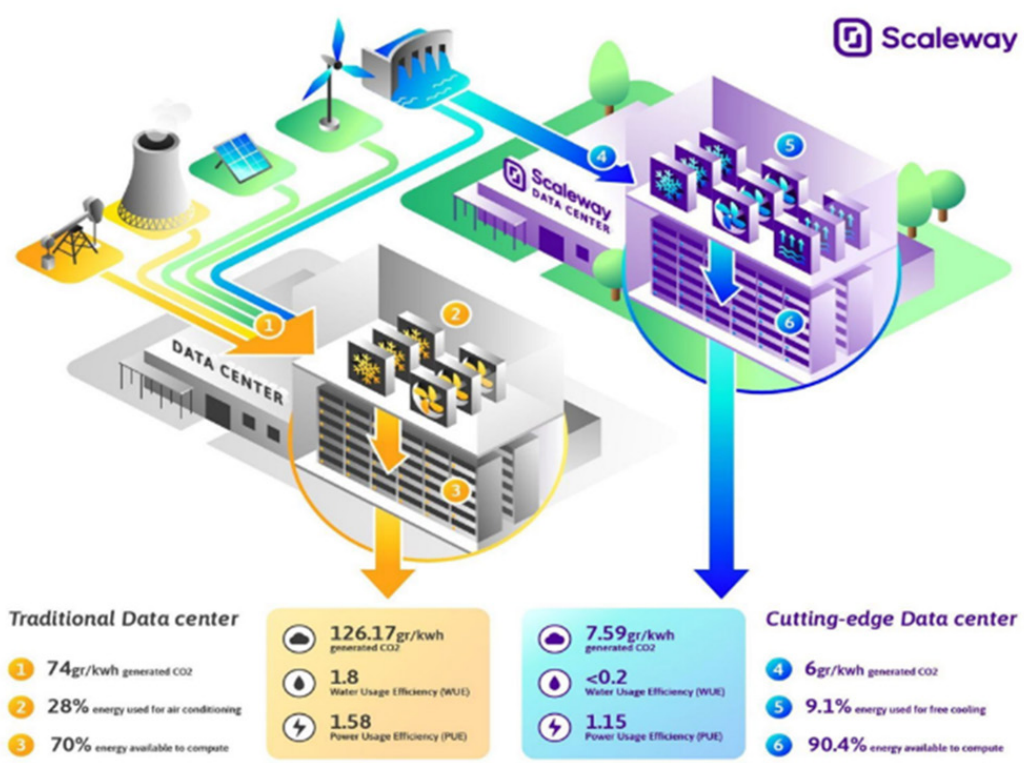
Figure 23: Benchmark of PUE for data centres in Europe (Source: Tactis)



c. **Circular economy and recycling**:

- **Scaleway**, a French cloud provider, is integrating circular economy practices by refurbishing and reusing hardware. Scaleway extends the lifespan of its servers by repurposing components, reducing electronic waste and the need for new hardware. This initiative aligns with France's broader goals of reducing e-waste and supporting a more sustainable, circular economy.

Figure 24: Scaleway environmental impacts actions (Image: Scaleway)

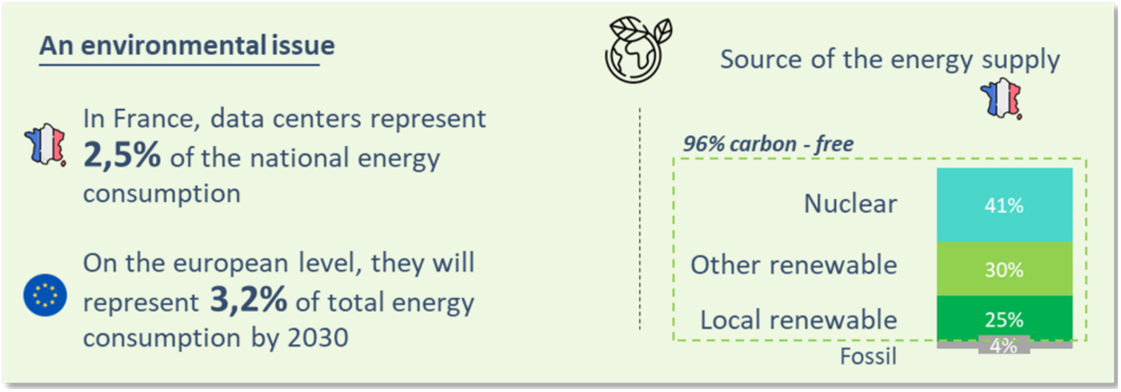


d. **Government regulations and support**:

- The **European Union's Green Deal** and the **Energy Efficiency Directive** set clear benchmarks for energy usage in data centres, aiming to improve energy efficiency by **32.5 per cent by 2030** across all sectors. France is implementing these regulations by incentivizing data centre operators to adopt more sustainable practices, including energy efficiency upgrades and the use of renewable energy.

- France's government has introduced tax incentives for companies that prioritize energy efficiency in their data centres. Additionally, the **France Relance** recovery plan allocates funding for green technologies and infrastructure, encouraging operators to adopt eco-friendly solutions.

Figure 25: Environmental impacts in Europe and France (Tactis)



e. **Sustainable certifications**:

- Many data centres in France are pursuing international sustainability certifications like the **ISO 50001** (Energy Management) and the **LEED (Leadership in Energy and Environmental Design)** certification. These certifications provide a framework for energy-efficient and environmentally responsible design and operation.
- For example, **Equinix** has committed to using **100 per cent renewable energy** in its French data centres and has achieved **LEED Gold certification** for many of its facilities, demonstrating its adherence to strict environmental and energy efficiency standards.

The French data centre market is on a clear path toward sustainability, with strong government support, increasing use of renewable energy, and innovations in energy efficiency and cooling technologies driving the industry's green transformation.

3 Challenges and opportunities

The data centre industry in France is composed for significant growth, but it also faces a range of challenges and opportunities as it continues to evolve. With the increasing demand for cloud services, big data, artificial intelligence, and 5G technologies, the French market is becoming a critical hub for both local and international players.

However, regulatory pressures, energy concerns, and competition pose obstacles that must be addressed for sustained growth.

Challenges

a. **Energy consumption and sustainability pressures**:

- One of the biggest challenges for the data centre industry in France is the **high energy consumption** required to power and cool facilities. As data demand grows, so too does the energy footprint of data centres, leading to concerns about environmental sustainability. Although France benefits from a high percentage of renewable energy (around **20 per cent** of electricity comes from renewable sources), data centres still face pressure to minimize their carbon footprints and optimize energy efficiency.

- To meet EU-wide sustainability goals such as the **European Green Deal**, data centres must implement energy-efficient designs, such as advanced cooling technologies and renewable energy sourcing, which can be costly and complex to integrate at scale. **Power Usage Effectiveness (PUE)**, a key metric of energy efficiency, is an ongoing focus, but reaching optimal levels can require significant investments.

b. **Regulatory compliance and data sovereignty**:

- **Data sovereignty** is becoming increasingly important as regulations like the **General Data Protection Regulation (GDPR)** enforce strict requirements for data privacy and the storage of personal data within national borders. Companies operating in the French data centre market need to ensure compliance with these rules, which can complicate operations, particularly for global operators handling cross-border data flows.
- Additionally, as the European Union intensifies its environmental regulations and energy efficiency directives, operators will face increasing pressure to align with policies that mandate reductions in carbon emissions and energy usage. Compliance with these regulations could increase operational costs and require operators to rethink their data centre strategies.

c. **Rising demand for skilled labour**:

- The growth of the data centre market is leading to increased demand for skilled labour in areas like data centre design, IT infrastructure management, and energy optimization. However, there is a shortage of specialized professionals with the necessary skills to meet this demand. Recruiting and retaining talent in these fields poses a challenge for operators, especially as competition intensifies both locally and globally.

d. **Land and infrastructure availability**:

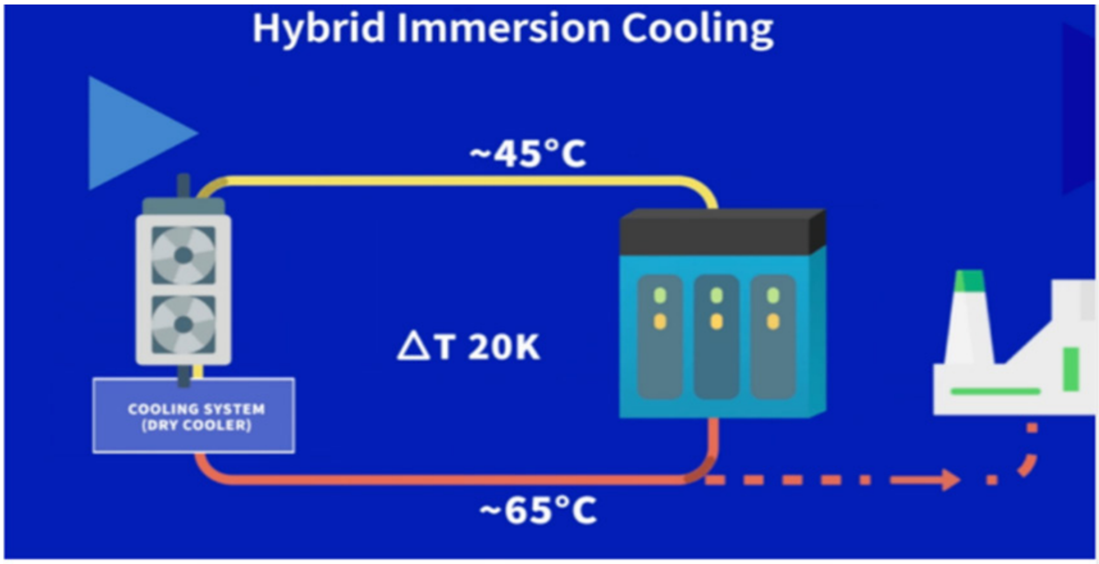
- Finding suitable land and infrastructure for data centre construction, particularly in urban centres like Paris, is becoming more difficult. Data centres require significant amounts of land, energy, and water resources, and securing all these elements at a competitive cost can be challenging, particularly in regions where real estate is limited or expensive.
- This constraint can limit the growth of new data centre projects and delay expansions, forcing operators to explore alternative locations or invest in edge data centres that require smaller footprints but present their own technological challenges.

Opportunities

a. **Sustainability as a competitive advantage**:

- While energy consumption presents a challenge, it also creates an opportunity for French data centres to differentiate themselves by accepting sustainability. Operators that lead in **green technologies** and **renewable energy sourcing** will not only reduce operational costs in the long term but also attract environmentally conscious customers. France's access to renewable energy, including **hydroelectric**, **wind**, and **solar power**, provides an opportunity for data centres to significantly reduce their carbon footprints.
- **OVHcloud**, for example, uses innovative **water-cooling** systems and sources renewable energy for its data centres, setting itself apart as a sustainable leader. French data centres can build on this momentum by adopting next-generation cooling technologies (such as liquid cooling) and implementing more energy-efficient designs, such as optimized airflow and renewable energy integration.

Figure 26: OVH water cooling system (OVH)



b. **Edge computing and 5G expansion**:

- The rise of **edge computing** represents a major growth opportunity for the French data centre market. As **5G networks** are rolled out, there will be an increasing demand for low-latency, decentralized computing, with data centres located closer to the end users. Edge data centres, which are smaller and distributed geographically, allow for faster processing and response times, particularly for IoT applications, autonomous vehicles, and real-time analytics.
- France's early adoption of 5G presents a strategic advantage for data centre operators that can capitalize on this trend by building edge facilities across the country. The **Paris region** is a key area for edge data centre growth, given its population density and technological demand.

c. **Government support for digital transformation**:

- The French government has placed digital infrastructure at the heart of its economic recovery plans, including the **France Relance** plan, which allocates **€7 billion** for digital transformation initiatives. A portion of this funding supports the expansion of data centres and cloud services, presenting an opportunity for operators to secure financial backing and incentives for building new facilities or upgrading existing ones.
- Additionally, the government's focus on **digital sovereignty** provides an opportunity for local data centre operators like **OVHcloud** and **Scaleway** to capture market share from international players, as many French businesses prefer to host their data domestically to ensure compliance with data sovereignty laws.

d. **Growing demand for colocation and cloud services**:

- With the rapid digital transformation of businesses across industries, there is a growing demand for **colocation** and **cloud services** in France. Companies are increasingly moving away from on-premises data centres to outsourcing their infrastructure needs to colocation providers or adopting hybrid cloud strategies. This shift creates opportunities for data centre operators to offer flexible and scalable services to a broad range of industries, including finance, healthcare, and retail.
- Major international players like **Equinix**, **Digital Realty**, and **Data4** are investing heavily in colocation facilities in France, while French players like **OVHcloud** and **Scaleway** are enhancing their cloud offerings to capture market share.

e. **Expansion of hyperscale data centres**:

- As cloud service providers such as **AWS**, **Google Cloud**, and **Microsoft Azure** expand their infrastructure in Europe, there is a growing need for **hyperscale data centres** in France. These large-scale facilities, designed to support massive data processing and storage requirements, offer significant opportunities for investment and collaboration between data centre operators and cloud providers. Hyperscale data centres are particularly important for serving the increasing demand for cloud services in Europe, and France is well-positioned to benefit from this trend due to its central location and strong infrastructure.

The data centre market in France is at a crucial moment, with significant growth opportunities driven by digital transformation, 5G, and sustainability. However, the industry must face challenges related to energy consumption, regulatory compliance, and skilled labor shortages. Those that successfully embrace sustainability and edge computing, while taking advantage of government support and increased demand for cloud and colocation services, stand to succeed in this competitive landscape.

Benchmarking metrics

Based on the metrics selection done by the country for benchmarking, a benchmark table is provided for Uganda's green data centres against Kenya, South Africa, and France based on **Power Usage Effectiveness (PUE)**, **Renewable Energy Usage**, and **Data Centre Security and Reliability.** Some insights will also be provided for the metric of **Latency and Bandwidth Capacity in Green Data Centres.**

The below table shows the summary analysis of each metric in detail, drawn from the data in these countries and applied in Uganda context.

1 Table of benchmarking metrics and use cases

<table>
<tr><th rowspan="2">Metrics</th><th rowspan="2">Definition</th><th colspan="3">Benchmarking comparison</th></tr>
<tr><th>Kenya</th><th>South Africa</th><th>France</th></tr>
<tr><td>Power Usage Effectiveness (PUE)</td><td>PUE measures the ratio of total energy consumed by the data centre to the energy used by IT equipment. The lower the PUE, the more energy-efficient the data centre is.</td><td>Leading data centres in Kenya have PUE values between 1.4 and 1.6.
For example, the East Africa Data Centre (EADC) by Liquid Intelligent Technologies has made significant progresses in improving its energy efficiency through better cooling systems and energy-efficient designs.</td><td>In South Africa, data centres like Teraco aim to reach PUE values of 1.3 by using solar energy and smart cooling systems.
However, challenges like load shedding (power outages) make maintaining optimal PUE more difficult.</td><td>France has some of the most energy-efficient data centres in the world, such as OVHcloud, which reports PUE values as low as 1.09.
This is achieved by water-cooling systems and renewable energy integration.</td></tr>
<tr><td colspan="5">Applications for Uganda:
• Recommendation: Uganda can aim for a PUE target of 1.4 to 1.6 as a starting point, like Kenya. This can be done by focusing on improving cooling efficiency and optimizing the design and layout of data centres (have more modulable data centres) to reduce energy waste.
• Example: Uganda can follow Kenya's model, such as in the iXAfrica data centre, which optimizes its PUE by using air-based cooling and leveraging local renewable energy resources.</td></tr>
<tr><td>Renewable Energy Usage</td><td>This metric measures the percentage of energy used by a data centre that comes from renewable sources such as solar, wind, or hydroelectric power.</td><td>Kenya is a global leader in renewable energy, with around 90% of its electricity grid powered by renewable sources, particularly geothermal and hydroelectric power.
Data centres in Kenya, such as those operated by Liquid Intelligent Technologies, are moving into this green energy grid, making them some of the most sustainable data centres in Africa.</td><td>South Africa has significant solar energy potential but still faces challenges due to its reliance on coal-based electricity.
However, companies like Teraco are investing in solar farms and exploring wind energy to offset this reliance.</td><td>France benefits from a high share of renewable energy, particularly hydropower, which powers a significant portion of its data centres.
For example, OVHcloud has committed to sourcing 100% renewable energy.</td></tr>
<tr><td colspan="5">Applications for Uganda:
• Recommendation: Uganda should prioritize integrating solar energy into its data centres, given its high solar potential. Partnerships with renewable energy providers could facilitate the integration of solar or hydropower into data centre operations.
• Example: Uganda can compete Kenya's renewable energy grid utilization, particularly in regions where hydropower or solar farms are feasible. Raxio Data Centre could follow the IXAfrica model in Kenya, which taps into the national renewable grid.</td></tr>
</table>

(continued)

Metrics	Definition	Benchmarking comparison		
		Kenya	South Africa	France
Data Centre Security	Security and reliability are important to ensure the integrity and continuous operation of a data centre. This metric assesses the strength of security measures in place to protect against cyber threats and physical attacks while ensuring operational continuity.	Security features: Kenya's leading data centres, such as East Africa Data Centre (EADC) in Nairobi, are equipped with advanced security measures including biometric access controls, 24/7 surveillance, and multiple layers of physical security. These data centres also implement fire suppression systems, intrusion detection, and data encryption to protect sensitive data. Digital security: Data centres like IXAfrica employ strong cybersecurity frameworks, including network firewalls, DDoS protection, and intrusion prevention systems (IPS) to defend against cyberattacks. Given the rise in cyber threats in Africa, Kenyan data centres also emphasize regular security audits and compliance with international security standards like ISO 27001. Example: EADC offers multi-layered security systems, from perimeter security to server room access controls, ensuring that only authorized personnel can access the infrastructure.	Security features: South Africa's Teraco Data Environments are known for their inflexible security protocols. Facilities include mantraps (high-security entrance points), biometric access controls, and 24/7 CCTV surveillance. Each facility also uses security guards, fenced perimeters, and video surveillance analytics to ensure maximum physical security. Digital security: South Africa has a robust cybersecurity ecosystem. Teraco uses next-generation firewalls, encryption technologies, and DDoS mitigation services to secure data. Additionally, the Protection of Personal Information Act (POPIA) mandates strict privacy and data protection standards, like GDPR in Europe. Example: Teraco's Cape Town facility employs tiered security zones, where access becomes progressively more restricted, ensuring that sensitive areas like server rooms are only accessible to authorized personnel.	Security features: France has some of the highest data centre security standards in Europe, with facilities like OVHcloud and Equinix using biometric access, mantraps, and 24/7 video monitoring as standard security measures. Additionally, security guards, perimeter defenses, and electronic access systems are employed to prevent unauthorized entry. Digital security: French data centres adhere to GDPR, which imposes strict data privacy and protection standards. Facilities like Scaleway and OVHcloud are certified under ISO 27001 and use advanced encryption methods, firewalls, and real-time monitoring systems to detect and prevent cyber threats. Additionally, they offer end-to-end encryption for sensitive data and regular security audits. Example: OVHcloud implements multi-factor authentication for access to its infrastructure, alongside 24/7 SOC (Security Operations Centre) monitoring to detect and respond to potential threats.

(continued)

Metrics	Definition	Benchmarking comparison		
		Kenya	South Africa	France
Data centre reliability		Reliability features: Kenya's EADC and other data centres are certified to Tier III standards, ensuring 99.982% uptime, which allows for 72 hours of power outage protection. These facilities are equipped with N+1 redundancy for power and cooling systems, which means that backup power and cooling are available in case of equipment failure. Disaster recovery: EADC offers disaster recovery and business continuity services, ensuring that data remains available even in the event of power failures or other emergencies. Facilities include backup generators, UPS systems, and advanced fire suppression technologies. Example: IXAfrica operates with Tier III infrastructure, providing robust redundancy and fault tolerance, ensuring that even in case of a component failure, the data centre continues to operate without downtime.	Reliability features: South Africa's Teraco operates at Tier III and Tier IV levels, offering 99.995% uptime in its Johannesburg and Cape Town facilities. This is achieved through 2N redundancy, meaning that there are two independent power and cooling systems, so if one fails, the other can immediately take over. Load shedding management: Due to South Africa's electricity challenges, including load shedding, Teraco has invested heavily in backup power systems such as large-scale battery storage and diesel generators to ensure continued operations during outages. Teraco also offers cross-connectivity and interconnection services, which enhance network reliability and redundancy. Example: Teraco's Johannesburg facility employs 2N power redundancy with dual power feeds, ensuring that the data centre can continue operations even during extended power outages.	Reliability features: French data centres, including those operated by OVHcloud and Equinix, are certified at Tier IV standards, offering 99.995% uptime, the highest level of reliability in the industry. These facilities incorporate 2N+1 redundancy, which includes two independent systems plus an additional backup in case of failure. Disaster recovery and redundancy: French data centres offer advanced disaster recovery options, including geo-redundancy, where data is replicated across multiple geographically distributed locations, ensuring business continuity even during natural disasters. UPS systems, backup generators, and advanced fire suppression mechanisms are in place to maintain operations without interruption. Example: Equinix Paris uses multi-tiered UPS systems, dual utility feeds, and cross-regional backups to ensure that even in the event of a major failure, services remain online.

(continued)

<table>
<tr><th rowspan="2">Metrics</th><th rowspan="2">Definition</th><th colspan="3">Benchmarking comparison</th></tr>
<tr><th>Kenya</th><th>South Africa</th><th>France</th></tr>
<tr><td colspan="5">Applications for Uganda:
• Recommendation for security: Uganda should aim to adopt multi-layered physical security like Kenya and South Africa, with biometric access controls, surveillance, and intrusion detection systems. Furthermore, data centres like Raxio Uganda should adhere to international security standards such as ISO 27001 to build trust and ensure data protection compliance.
• Example: Raxio Data Centre can follow OVHcloud's model by implementing biometric access, multi-factor authentication, and real-time monitoring systems to protect both physical and digital assets from unauthorized access.
• Recommendation for reliability: Uganda should aim to achieve Tier III certification for its data centres, ensuring 99.982% uptime with N+1 redundancy for both power and cooling. Given the challenges with Uganda's electricity supply, facilities like Raxio Data Centre should invest in solar energy or battery storage systems as backup power solutions to maintain continuous operations.
• Example: Raxio Data Centre could follow Teraco's model in South Africa by implementing large-scale battery storage systems to mitigate power outages and ensure that operations continue smoothly during grid disruptions.</td></tr>
<tr><td>Latency</td><td>Latency refers to the time it takes for data to travel between a data centre and an end user. Low latency is essential for real-time applications such as online gaming, financial services, and video conferencing.</td><td>Kenya benefits from its connection to several submarine cables at Mombasa, such as the Eastern Africa Submarine Cable System (EASSy), TEAMS, and SEACOM. This robust fiber-optic infrastructure significantly reduces latency, making Kenya a regional hub for data traffic in East Africa.
Major data centres like East Africa Data Centre in Nairobi offer relatively low latency services, primarily due to their strategic location and international bandwidth.
Example: Nairobi's data centres typically experience latencies below 50 ms for regional traffic and improved speeds for international connectivity due to these undersea cables.</td><td>South Africa's data centres, particularly in Johannesburg and Cape Town, are connected to multiple undersea cables such as ACE (Africa Coast to Europe) and WACS (West Africa Cable System). These connections allow for latencies as low as 5 to 20 ms for regional traffic, with slightly higher latency for international traffic depending on the destination.
Example: Data centres like Teraco benefit from low-latency interconnections between major cities in South Africa, allowing them to serve as a hub for Sub-Saharan Africa.</td><td>France's data centres benefit from being in Europe's well-developed network infrastructure, which ensures extremely low latencies for both regional and international traffic.
Latency in France's data centres can be as low as 1-10 ms for domestic and regional traffic within Europe. France's central position in Europe, connected by multiple terrestrial fiber-optic networks, makes it one of the most efficient locations for global internet traffic.
Example: Major providers like OVHcloud and Scaleway in Paris experience extremely low latencies, making them ideal for hosting latency-sensitive applications such as high-frequency trading and streaming services.</td></tr>
</table>

(continued)

Metrics	Definition	Benchmarking comparison		
		Kenya	South Africa	France
Applications for Uganda: • Recommendation: Uganda should focus on improving its position as a transit country for submarine and terrestrial fiber-optic connections to reduce latency, particularly for regional and international traffic. Uganda's Raxio Data Centre can be optimized by linking to undersea cables via Kenya and improving the National Optic Fiber Backbone Infrastructure (NOFBI), as Kenya has done. • Target: Latency under 50 ms for regional traffic and closer to 100-150 ms for international connections could be achievable by linking directly to regional undersea cables such as SEACOM or EASSy.				
Bandwidth capacity	Bandwidth capacity refers to the maximum rate at which data can be transmitted over a network. High bandwidth ensures faster data transfer rates, critical for handling large volumes of data, cloud services, and content delivery.	Kenya's fiber-optic backbone and multiple undersea cables give it significant bandwidth capacity, enabling data centres like the East Africa Data Centre to offer high-speed internet connections and reliable services for cloud computing and colocation. Kenya's internet service providers (ISPs) have access to vast bandwidth, allowing for competitive services to end users and businesses. Example: Kenya's national bandwidth capacity is estimated to be in multi-terabits per second (Tbps) due to its connectivity to multiple submarine cables, providing sufficient bandwidth for growth in cloud services and content delivery.	South Africa has some of the largest bandwidth capacities in Africa, with substantial investments in both undersea cables and national fiber infrastructure. With connections to cables like ACE, WACS, and SAT-3, data centres in South Africa, such as Teraco, offer services with multi-Tbps bandwidth capacity. Example: The growth of hyperscale data centres like those of AWS and Microsoft Azure in South Africa indicates that South Africa has enough bandwidth to handle massive data transfers, cloud workloads, and content delivery services.	France benefits from being part of Europe's high-capacity fiber network, with bandwidth capacities in the multi-terabit range across the country. Major international carriers, ISPs, and cloud service providers have access to extremely high bandwidths, enabling rapid data transfers and ultra-low latency for global services. Example: OVHcloud and Scaleway offer data centre services with tens of terabits per second (Tbps) bandwidth, capable of supporting large-scale cloud services, content delivery networks (CDNs), and high traffic applications.
Applications for Uganda: • Recommendation: Uganda should leverage on its transit position to expand its fiber-optic network and increase its connections to submarine cables through Kenya. This would significantly boost the bandwidth capacity for its data centres, making them competitive for cloud services, colocation, and content delivery. • Example: Uganda could leverage the model followed by South Africa's Teraco, which ensures high bandwidth by connecting to multiple international undersea cables. By developing partnerships with ISPs and global carriers, Uganda's data centres could offer higher bandwidths to meet the needs of international clients and local businesses.				

2 Summary of key metrics for benchmarking Uganda

Metric	Kenya	South Africa	France	Uganda (target)
PUE	1.4 – 1.6	1.3 – 1.4	1.09 – 1.2	1.4 – 1.6
Renewable Energy Usage	90% from renewable sources (Geothermal, Hydro)	Solar energy + wind energy (starting)	100% renewable energy (Hydropower, Wind)	Solar power + hydropower integration
Data centre security	Biometric access, 24/7 CCTV, ISO 27001	Mantraps, 24/7 CCTV, next-gen firewalls	Biometric, multi-factor authentication, GDPR	Biometric access, ISO 27001, CCTV, encryption
Data centre reliability	Tier III, 99.982% uptime, N+1 redundancy	Tier III/IV, 99.995% uptime, 2N redundancy	Tier IV, 99.995% uptime, 2N+1 redundancy	Tier III, 99.982% uptime, N+1 redundancy
Backup Power Systems	Backup generators, UPS, disaster recovery	Solar + battery storage, diesel generators	UPS, geo-redundancy, backup generators	Backup generators, UPS, battery storage
Disaster recovery	Disaster recovery and business continuity plans	Load shedding management, interconnectivity	Geo-redundancy, cross-regional backups	Disaster recovery plans, UPS, backup power
Latency	50 ms (regional), 100-200 ms (international)	5-20 ms (regional), 100-150 ms (international)	1-10 ms (regional), 100-150 ms (international)	50 ms (regional), 100-150 ms (international)
Bandwidth capacity	Multi-Tbps capacity from SEACOM, EASSy, etc.	Multi-Tbps from WACS, ACE, SAT-3	Multi-Tbps from terrestrial and submarine links	Multi-Tbps by linking with SEACOM, EASSy

International studies and guidelines

To support Uganda's initiatives in developing green data centres with an emphasis on improving latency, bandwidth capacity, energy efficiency, and overall sustainability, there are numerous international studies and guidelines from organizations like the **International Telecommunication Union (ITU)** and **Smart Africa Alliance** that we have consulted.

Below is a summary of texts and studies from these organizations that align with the findings and recommendations for Uganda's data centre development.

1 International Telecommunication Union (ITU)

ITU has published several reports and recommendations on building sustainable, energy-efficient data centres and improving ICT infrastructure in developing countries. Recommendation ITU-T L.1300[68] and Recommendation ITU-T **L.1380**[69] series offer a detailed framework for the design, operation, and energy optimization of data centres.

[68] https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-L.1300-201406-I!!PDF-E&type=items
[69] https://standards.globalspec.com/std/14228005/itu-t-l-1380

Key studies and texts:

a. **Recommendation ITU-T L.1300: "Best practices for green data centres"**

- This recommendation provides a comprehensive guide for reducing the environmental impact of data centres, focusing on **Power Usage Effectiveness (PUE)**, **energy efficiency**, and the adoption of **renewable energy sources**.
- **Text reference**: "Energy efficiency is a key element in data centres for ensuring lower environmental impact and operational costs. Developing economies like Uganda can benefit from adopting advanced cooling techniques, renewable energy integration, and optimizing power usage as outlined in the ITU-T L.1300 guidelines."
- **Application to Uganda**: ITU recommendation for green data centres, including the focus on PUE, renewable energy, and advanced cooling technologies, aligns with Uganda's goal to develop sustainable, energy-efficient infrastructure.

b. **Recommendation ITU-T L.1380: "Sustainable and energy-efficient data centre infrastructure"**

- This standard addresses the need for ICT facilities to adopt sustainable practices and infrastructure, emphasizing **energy efficiency**, **carbon footprint reduction**, and **disaster recovery capabilities**.
- **Text Reference**: "For countries in Africa, such as Uganda, ITU-T L.1380 recommends focusing on enhancing the sustainability of ICT infrastructure through energy-efficient cooling systems and low-carbon power sources. This supports both environmental sustainability and the development of digital economies."
- **Application to Uganda**: These guidelines support Uganda's integration of renewable energy sources and advanced cooling techniques, such as those employed by data centres in Kenya and France.

2 Smart Africa Alliance

The **Smart Africa Alliance**, a pan-African initiative, focuses on enhancing digital infrastructure across the continent. It has been advocating for sustainable ICT development, with a specific focus on improving broadband connectivity and developing efficient data centres.

Key studies and texts:

a. **Smart Africa Manifesto: "Smart Broadband 2025"**[70]

- This initiative promotes high-speed broadband deployment across Africa, which directly relates to improving **latency** and **bandwidth capacity** for data centres.
- **Text reference**: "Smart Africa's focus on improving broadband infrastructure emphasizes the need for strong regional and international connectivity through undersea cables and national fiber-optic networks. This will reduce latency and increase bandwidth for Uganda's data centres, making them competitive with other African countries like Kenya and South Africa."
- **Application to Uganda**: Uganda can leverage Smart Africa's goals to improve fiber-optic networks and submarine cable connections, thus aligning with the regional focus on latency reduction and bandwidth capacity improvements.

70 https://smartafrica.org/wp-content/uploads/2020/12/SMART-BROADBAND-2025-Layout.pdf

b. **Smart Africa Report: "Sustainable Data Centres in Africa"**[71]

- This report provides guidelines for building sustainable data centres that incorporate **energy-efficient technologies**, **renewable energy** usage, and **disaster recovery** mechanisms.
- **Text reference**: "As Africa's digital economy grows, it is essential that data centres adopt sustainable practices. This report highlights the importance of integrating renewable energy, improving PUE, and adopting efficient cooling methods. Uganda, by following these guidelines, can position itself as a leader in green ICT infrastructure in East Africa."
- **Application to Uganda**: Uganda's data centre strategy can be framed around the sustainable goals set by Smart Africa, especially in adopting solar energy, improving PUE, and ensuring data centre reliability through improved cooling systems.

3 The Global Enabling Sustainability Initiative (GeSI)

GeSI provides insights into how ICT can contribute to environmental sustainability, particularly in developing regions. It aligns with global green data centre initiatives by offering tools and frameworks that help countries optimize their data infrastructure.

Key studies and texts:

a. **GeSI SMARTer 2030 Report: "ICT Solutions for 21st Century Challenges"**[72]

- This report explores the potential for ICT to reduce global carbon emissions while enabling economic growth, with a focus on data centre efficiency and renewable energy integration.
- **Text reference**: According to GeSI SMARTer 2030 report, ICT innovations, including green data centres, can reduce global CO2 emissions by up to 20%. For Uganda, this means that by adopting green technologies in its data centres, the country cannot only grow its digital economy but also contribute to global sustainability goals."
- **Application to Uganda**: Uganda can draw from these findings to emphasize renewable energy and cooling efficiency as part of its green data centre strategy, aligning with GeSI's vision for reducing emissions through sustainable ICT practices.

4 The African Development Bank (AfDB)

The AfDB supports sustainable infrastructure projects across Africa, including ICT initiatives. Its focus on **green growth** and **renewable energy projects** aligns with Uganda's vision for sustainable data centre development.

Key Studies and Texts:

a. **AfDB's "Africa's Digital Transformation Strategy 2020–2030"**[73]

- This strategy emphasizes the importance of building **resilient ICT infrastructure**, including data centres, with a focus on sustainability, energy efficiency, and regional collaboration.

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71 https://smartafrica.org/the-role-of-african-governments-and-multilateral-organizations-in-increasing-the-footprints-of-multi-tenant-data-centres-and-cloud-infrastructure-in-africa/

72 https://www.gesi.org/research/smarter2030-ict-solutions-for-21st-century-challenges#:~:text=This%20report%20shows%20that%20ICT,economic%20growth%20from%20emissions%20growth.

73 https://au.int/en/documents/20200518/digital-transformation-strategy-africa-2020-2030

- **Text reference**: "To meet the growing demand for digital services, AfDB recommends that African nations, including Uganda, invest in green data centre infrastructure that maximizes energy efficiency and promotes the use of renewable energy sources. The strategy highlights the importance of regional collaboration in improving bandwidth and reducing latency through cross-border fiber-optic networks."
- **Application to Uganda**: The AfDB's digital transformation strategy provides a roadmap for Uganda to focus on **cross-border connectivity**, **latency reduction**, and **energy-efficient practices** in its data centre development.

5 GSMA Mobile Economy Reports

GSMA, which focuses on mobile and digital economy growth in emerging markets, has emphasized the need for green and efficient ICT infrastructure, particularly in mobile-driven economies like Uganda.

Key studies and texts:

a. **GSMA Report: "Building Sustainable ICT Infrastructure in Emerging Markets"**[74]

- This report highlights the need for mobile and broadband services to be supported by **sustainable, energy-efficient data centres**.
- **Text reference**: "As mobile connectivity drives the digital economy in Uganda, GSMA recommends that data centres adopt green technologies to ensure long-term sustainability. By using renewable energy and energy-efficient cooling systems, Uganda can reduce operational costs and improve its competitiveness in the region."
- **Application to Uganda**: The adoption of green technologies in Uganda's data centres will align with GSMA's recommendations, particularly in a mobile-first economy where energy-efficient infrastructure is essential for scaling broadband services.

Conclusions and recommendations

Uganda's data centre industry is positioned for significant growth, driven by the rapid digital transformation of key sectors such as telecommunications, government services, colocation, financial technology (FinTech), and cloud computing. However, the country faces several challenges that must be addressed to ensure that the development of data centres aligns with both sustainability goals and international standards.

The benchmarking analysis of Uganda's data centres against those in Kenya, South Africa, and France has provided valuable insights into areas for improvement, best practices, and strategies to overcome existing barriers.

Below are the key recommendations derived from this benchmark report.

1 Energy efficiency and Power Usage Effectiveness (PUE)

- **Recommendation**: Uganda must prioritize improving the energy efficiency of its data centres. A key focus should be on achieving a low PUE, which reflects the ratio of total energy consumed by the data centre versus the energy consumed by IT equipment alone.
  - **Action plan**: Implement advanced cooling systems, including air and water-cooling technologies, to reduce energy consumption for temperature control. This should

[74] https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-for-development/blog/sustainable-impact-scaling-digital-innovation-in-africa/

include optimizing server infrastructure through virtualization to decrease the number of physical servers required, further reducing power usage.

- **Goal**: Aim to achieve a PUE ratio between 1.4 and 1.6, aligning with international best practices seen in countries like Kenya and South Africa.

2 Adoption of renewable energy

- **Recommendation**: Accelerate the integration of renewable energy sources, such as solar and hydropower, into Uganda's data centre operations.
  - **Action plan**: Partner with national energy providers to secure a greater share of Uganda's already substantial renewable energy production, particularly solar energy, for powering data centres. Facilities like Raxio Data Centre have already set a precedent by planning to incorporate solar energy.

Goal: Transition to at least 50 per cent renewable energy in data centre operations within the next five years, leveraging Uganda's high renewable energy potential.

3 Green growth incentives

- **Recommendation**: Collaborate with government entities (UCC) to develop and promote green growth policies and incentives that encourage investments in energy-efficient technologies and renewable energy solutions.
  - **Action plan**: Take advantage of Uganda's green growth strategy under the National Development Plan III by offering tax incentives or subsidies for data centres that adopt energy-efficient designs and utilize renewable energy.
  - **Goal**: Establish Uganda as a regional key-player in green data centres, attracting investment from global tech companies interested in sustainable infrastructure.

4 Enhancing data centre reliability and security

- **Recommendation**: Improve the reliability and security of data centres by adopting international best practices in disaster recovery, redundancy, and cybersecurity.
  - **Action plan**: Implement multi-tiered backup power solutions such as solar energy with battery storage systems and UPS (uninterruptible power supplies) to ensure continuous operation during power outages. Additionally, strengthen data centre security through advanced biometric access control, CCTV surveillance, and ISO 27001 certification.
  - **Goal**: Achieve Tier III certification for all major data centres (Raxio, NITA-U, MTN), ensuring 99.982 per cent uptime and operational reliability.

5 Building local capacity and skilled workforce

- **Recommendation**: Address the shortage of skilled professionals needed to manage and operate green data centres by investing in training and partnerships with international firms.
  - **Action plan**: Develop training programs focused on ICT infrastructure management, energy efficiency technologies, and advanced cooling systems. Engage in partnerships with international organizations (Smart Africa Digital Academy, ITU) to provide skills development opportunities.
  - **Goal**: Establish Uganda as a hub for skilled professionals in the data centre industry, ensuring local talent can support the growth of the sector.

6 Encouraging data localization

- **Recommendation**: Encourage compliance with Uganda's data localization laws, which require that sensitive data be stored within the country, by investing in local data infrastructure.
    - **Action plan**: Expand the national fiber-optic backbone to ensure low-latency, high-bandwidth connections for data centres, making it more attractive for businesses to host data locally rather than relying on international centres.
    - **Goal**: Promote Uganda as a secure data hub in East Africa, reducing the reliance on external facilities while improving data sovereignty and security.

7 Promoting partnerships and regional collaboration

- **Recommendation**: Promote partnerships with regional and international bodies to further the development of green data centres.
    - **Action plan**: Engage with organizations like the International Telecommunication Union (ITU), the African Development Bank (AfDB), and Smart Africa to align Uganda's data centre growth with regional sustainability initiatives.
    - **Goal**: Position Uganda as a competitive location for global cloud providers by improving infrastructure through regional collaborations.

Uganda's transition to a green data centre ecosystem will be critical in supporting its digital economy while minimizing environmental impact.

By adopting global best practices in energy efficiency, renewable energy usage, and sustainability standards, Uganda can attract international investment, reduce operational costs, and contribute to its climate goals.

Implementing these recommendations will not only strengthen Uganda's position as a regional key-player in digital infrastructure but also ensure that the country's data centres are resilient, reliable, and environmentally responsible.

Abbreviation table

ACE	Africa Coast to Europe
AfDB	African Development Bank
AWS	Amazon Web Services
CAGR	Compound Annual Growth Rate
CAK	Communications Authority of Kenya
EACO	East African Communications Organization
EASSy	Eastern Africa Submarine Cable System
ESG	Environmental, Social, Governance
FinTech	Financial Technology
GDPR	General Data Protection Regulation
GeSI	Global Enabling Sustainability Initiative
GSMA	Global System for Mobile Communications Association
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communication Technology
IFC	International Finance Corporation
ITU	International Telecommunication Union
LEED	Leadership in Energy and Environmental Design
MTN	Mobile Telecommunications Network
NBI	National Backbone Infrastructure
NEMA	National Environment Management Authority
NIRA	National Identification and Registration Authority
NITA - U	National Information Technology Authority Uganda
POPIA	Protection of Personal Information Act
PUE	Power Usage Effectiveness
PUE	Power Usage Effectiveness
REIPPPP	Renewable Energy Independent Power Producer Procurement Program
SADA	Smart Africa Digital Academy
SAT-3	South Atlantic 3
SEforALL	Sustainable Energy for All
SMEs	Small and Medium sized Enterprises

(continued)

TEAMS	The East African Marine System
UCC	Uganda Communications Commission
UPS	Uninterruptible Power Supply
URA	Uganda Revenue Authority
Utel	Uganda Telecom Limited
WACS	West Africa Cable System

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Annex 3: Green National Data Centre Standards and Guidelines

1 Introduction

1.1 Context and Challenges of Green Data Centres in Uganda

Uganda is experiencing rapid growth in its information and communication technology (ICT) sector, fueled by rising internet penetration rates and increasing demand for data services. Data Centres play a key role in this digital transformation by providing essential infrastructure for data storage, management, and processing. However, the rapid expansion of these facilities also drives up energy consumption and environmental impact, creating significant sustainability challenges.

In this context, green or ecological Data Centres emerge as a crucial solution. They aim to reduce the carbon footprint and environmental impacts of these critical infrastructures while meeting performance, security, and reliability requirements. Standards for green Data Centres in Uganda are part of an effort to promote responsible practices that meet the needs of the digital economy while adhering to national sustainable development goals.

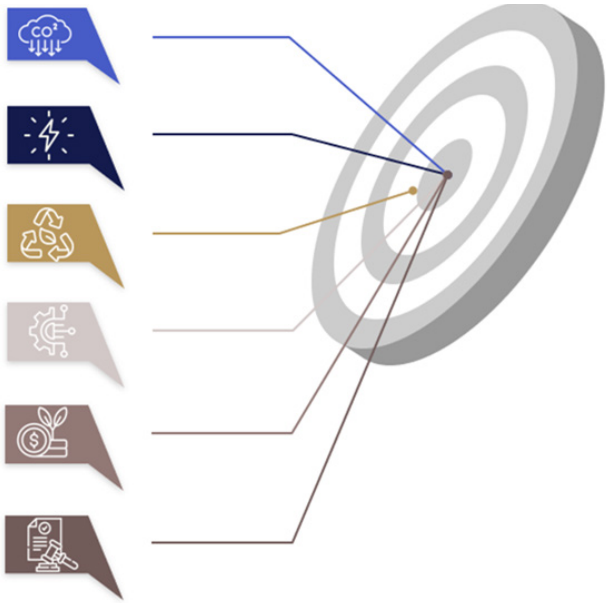
1.2 Importance of National Standards for Green Data Centres

Standards for green Data Centres establish a common framework for the design, construction, and operation of these facilities with minimized environmental impact. They provide a foundation for harmonizing practices and encourage the adoption of environmentally-friendly technologies and methods. By integrating clear and measurable criteria, these standards will help Data Centre operators in Uganda achieve specific sustainability goals and align their operations with international best practices.

Implementing these standards is also essential for attracting green investments, enhancing environmental responsibility initiatives, and positioning Uganda as a regional leader in sustainable digital infrastructure. By promoting ecological practices, Uganda can demonstrate its commitment to sustainability, strengthening its appeal to technology companies and international partners concerned with climate issues.

1.3 Objectives of Green Data Centre Standards in Uganda

The development of standards for green Data Centres in Uganda pursues several objectives, including:



- **Carbon Footprint Reduction**: Encouraging practices and technologies that minimize greenhouse gas emissions associated with Data Centre operations.
- **Energy Efficiency**: Optimizing Data Centre energy consumption by adopting high-efficiency cooling systems and IT equipment and using renewable energy sources whenever possible.
- **Responsible Natural Resource Management**: Reducing resource use, including water for cooling and rare materials in equipment, by adopting sustainable management practices and promoting recycling and reuse.
- **Promotion of Technological Innovation**: Encouraging the integration of new green technologies (such as artificial intelligence for energy management) and innovative design methods that can reduce the environmental impact of Data Centres.
- **Encouraging Responsible Investments**: By establishing sustainability standards, Uganda attracts environmentally-friendly investments, enhancing the country's competitiveness in the digital sector while respecting ecological imperatives.
- **Compliance with International Commitments**: These standards align with global environmental and climate goals, including the United Nations Sustainable Development Goals (SDGs) and international climate **agreements**. They enable Uganda to actively contribute to global emissions reduction and climate change mitigation.

1.4 Structure of the Standards and Guidelines Report

This report details the standards and guidelines for implementing green Data Centres in Uganda. Each chapter explores key aspects of Data Centre sustainability, from design to operation, including construction. The report is structured as follows:

- **Environmental Impact Assessment**: An in-depth analysis of the environmental impacts of current Data Centres and potential improvements.
- **Catalogue of International Certifications and Labels**: A review of ecological certifications and their relevance to the Ugandan context.
- **Design, Construction, and Operational Standards**: A set of recommendations for each phase of the Data Centre lifecycle, aimed at minimizing ecological impact while maximizing operational efficiency.
- **Summary of Guidelines**: A summary of standards and guidelines in a dashboard format, facilitating the implementation and tracking of ecological criteria.

2 Challenges of Data Centres: Strategic and Environmental Dimensions

2.1 Definition of a Data Centre

A **data centre** is a centralized facility used to house an organization's IT operations and equipment, including servers, storage systems, networking devices, and support infrastructure. These facilities are designed to provide secure, reliable environments that ensure the uninterrupted operation of critical digital systems and data storage.

Data centres typically include the following key components:

1. **IT Infrastructure**: Hardware such as servers, storage devices, and networking equipment responsible for data processing, storage, and communication.
2. **Power Systems**: Electrical infrastructure that includes uninterruptible power supplies (UPS), backup generators, and power distribution units (PDUs) to maintain continuous power.
3. **Cooling and HVAC Systems**: Climate control technologies to regulate temperature and humidity, ensuring the optimal operating environment for IT equipment.
4. **Network Connectivity**: High-speed connections that link the data centre to the internet or private networks, facilitating data exchange and communication.
5. **Security Systems**: Measures such as firewalls, biometric access controls, and surveillance to protect physical and digital assets.
6. **Building and Structural Design**: Architecture that includes fire protection, seismic resistance, and energy-efficient construction to support operations and sustainability goals.

Data centres are categorized based on their size, scalability, and performance reliability, often guided by international standards like the Uptime Institute's Tier Classification. They are integral to supporting the digital economy, hosting applications, managing data, and enabling cloud services.

Their environmental impact, as discussed in the following sections, highlights the need for sustainable designs and operational practices to minimize energy consumption, optimize resource use, and reduce greenhouse gas emissions.

2.2 Strategic Challenges of Data Centres

Data centres, which support digital transformation and are the backbone of modern organizations, face several major challenges:

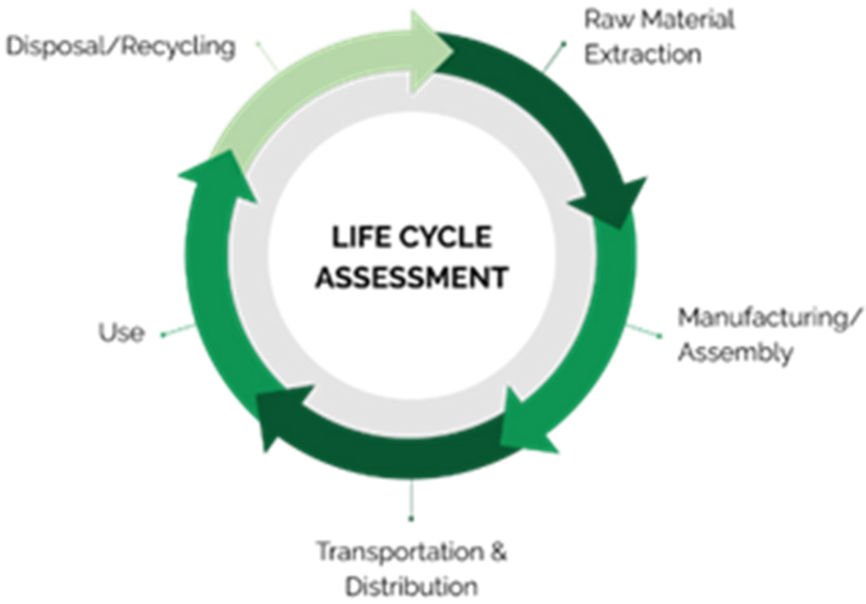
1. **Resilience and Business Continuity**: Ensuring uninterrupted operation and high availability of critical services, which are essential for managing digital workflows.
2. **Physical and Logical Security**: Protecting infrastructure and sensitive data through advanced cybersecurity measures and rigorous physical access controls.
3. **Energy and Environmental Performance**: Reducing energy consumption, limiting greenhouse gas emissions, and integrating sustainable technological solutions to minimize environmental impact while complying with regulatory requirements.

These challenges demand innovative solutions and sustainable management, combining technological performance with ecological responsibility to meet the growing needs of digital economy stakeholders.

2.3 Environmental Footprint of Data Centres

Data Centres play a crucial role in the digital economy, but their energy-intensive nature makes them significant contributors to greenhouse gas (GHG) emissions. Understanding and addressing their environmental footprint is essential to align with sustainability goals and reduce climate impact.

We will be using the LCA method, or Life Cycle Analysis, to assess the project's environmental impacts. This is a technique used to assess the environmental impacts of a product, service, or process throughout its life cycle (from the materials' extraction, to manufacturing, its use, and finally the end of the project's service life).



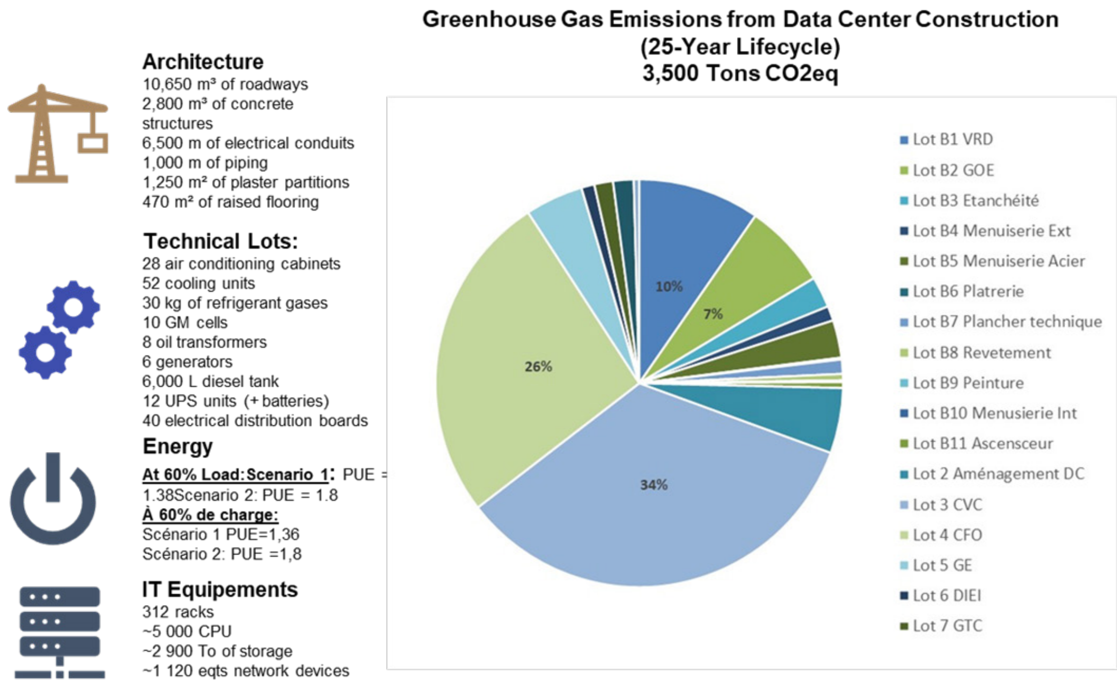
It is a standardised method (regulated by the ISO 14040 and 14044 standards) that can be used to transform the flows into potential environmental impacts.

Modelling produced with the LCA method can identify scenarios that reduce environmental impacts by avoiding pollution transfers.

The following standards are applicable for this approach:

- ISO 14040: 2006 Environmental management - Life cycle assessment - Principles and framework
- ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines
- The requirements of French and European environmental projects
- Future requirements published in the framework of Digital Services Product Category Rules (PCR)

The APL Data Center has life cycle analysis tools and up-to-date databases for modelling the data centre's greenhouse gas emissions. As an example, the following elements represent the greenhouse gas emissions of a data centre hosting a 600 m^2 computer room.



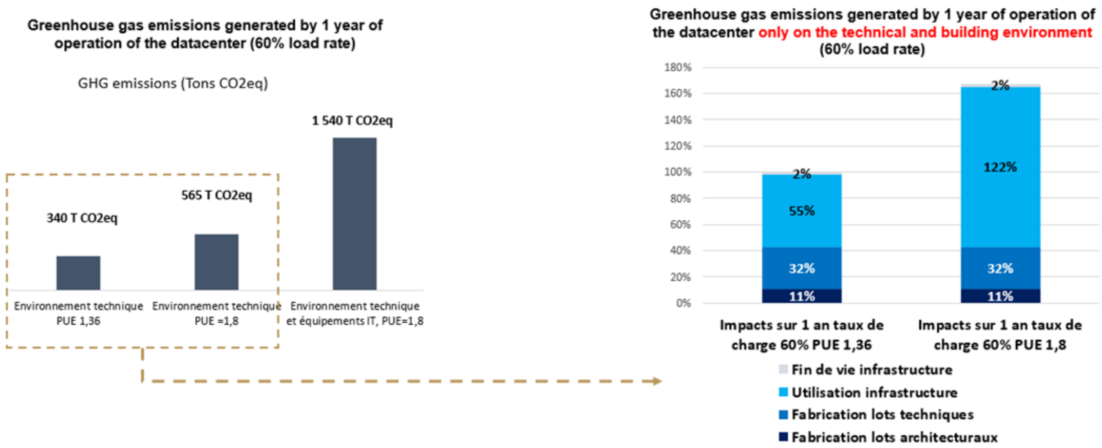
In this example, the main contributors to greenhouse gas emissions are the following lots:

- VRD (road and drainage works)
- Structural works
- HVAC (CVC)
- CFO (high-voltage and electrical systems)

Efforts should focus on these lots as a priority to reduce the environmental impact of Data Centre construction.

We can see that the data centre's annual greenhouse gas emissions can vary greatly, depending on which scope is considered. If we consider the overall scope (technical and building environment, plus the hosted computer equipment), the annual emissions for a 60% load rate are the equivalent of 1,540 tonnes of CO_2. The technical environment is responsible for just over a third of the data centre's total GHG emissions (by integrating the impact of the hosted equipment). Furthermore, when considering the scope comprising the technical and building environment, we can see that the energy performance level has a strong impact on the results: +70 per cent for a PUE of 1.8 rather than 1.36.

Consequently, these work packages must be dealt with first in order to reduce the environmental impact of the data centre's construction.



A range of solutions can be considered that can potentially be applied throughout the sites' life cycles (landscape integration, choice of materials, choice of equipment, energy processes, sustainable site management, operation and circularity, ...)

3 Catalogue of International Certifications and Labels

Data Centres, as essential infrastructures in an increasingly digital world, consume significant amounts of energy and resources. To address environmental challenges, a structured framework is needed to guide their design, construction, and operation sustainably. Ecological certifications and labels play a critical role here by establishing measurable standards to optimize energy efficiency, reduce CO_2 emissions, and minimize ecological impact.

This catalogue of certifications and labels provides an overview of international standards applicable to green Data Centres, detailing their objectives, criteria, and relevance for various stages of infrastructure lifecycle in Uganda. Through these certifications, Data Centres can demonstrate their commitment to sustainability and strengthen their competitiveness in the global digital sector.

3.1 Presentation of Ecological Certifications and Labels

3.1.1 ISO 14001 - Environmental Management Systems

- **Objective:** Establish a systematic framework to monitor, reduce, and improve the environmental impact of Data Centres at every stage of their lifecycle.
- **Description:** ISO 14001 is a widely recognized environmental management standard. It guides organizations in identifying, managing, and reducing their ecological footprint. For Data Centres, this means integrating sustainable management practices from design through construction to operation, including actions like resource optimization, waste management, and CO_2 emission reduction.
- **Benefits:**
  - **Regulatory Compliance**: Adherence to ISO 14001 prepares Data Centres to meet local and international environmental requirements.
  - **Operational Cost Reduction**: Efficient resource and waste management reduces operational costs.
  - **Enhanced Reputation**: ISO 14001 is an internationally recognized certification, attracting investors concerned with sustainable practices.

- **Commitment to Continuous Improvement**: Regular audits under ISO 14001 drive Data Centres to achieve higher environmental performance.

3.1.2 ISO 50001 - Energy Management Systems

- **Objective**: Improve Data Centre energy efficiency by implementing an energy management system for ongoing energy optimization.
- **Description**: ISO 50001 provides a framework for monitoring, analyzing, and managing energy consumption, introducing processes to reduce energy needs. This standard helps Data Centres develop strategies to maximize energy efficiency, which is often a significant cost factor in these facilities.
- **Benefits**:
  - **Cost Reduction**: Optimizing energy consumption lowers electricity expenses, a major component of Data Centre costs.
  - **Reduced CO_2 Emissions**: By using less energy, Data Centres also reduce their carbon footprint.
  - **Measurable Efficiency**: ISO 50001 provides indicators and monitoring processes to quantify energy savings.
  - **Flexibility and Adaptability**: The standard can be adapted to existing infrastructures, promoting effective energy management practices.

3.1.3 LEED (Leadership in Energy and Environmental Design)

- **Objective**: Promote sustainable design and construction practices for new Data Centres, reducing their environmental impact from the outset.
- **Description**: LEED is a sustainable construction certification focused on nine areas: energy efficiency, indoor air quality, water management, use of sustainable materials, and innovation. It includes specific options for Data Centres, adapting criteria to their technical and operational needs.
- **Benefits**:
  - **Global Recognition**: LEED is a prestigious label that attracts international investors and clients.
  - **Environmental Impact Reduction**: LEED-certified buildings consume less energy and water, reducing their environmental impact.
  - **Lower Operating Costs**: Sustainable construction practices often result in long-term savings.
  - **Improved Employee Health and Well-being**: Ensuring optimized air quality and indoor materials, LEED creates healthier work environments.

3.1.4 Green Grid - Power Usage Effectiveness (PUE)

- **Objective**: Measure and improve the energy efficiency of IT equipment in Data Centres, enabling managers to understand where and how energy is consumed.
- **Description**: PUE is a standardized indicator by Green Grid that measures energy efficiency by calculating the ratio between total Data Centre energy consumption and that used specifically by IT equipment. A low PUE means less energy is wasted in support activities (cooling, auxiliary power, etc.).

- **Benefits**:
  - **Simplified Energy Consumption Tracking**: PUE provides a simple way to measure and compare energy efficiency.
  - **Continuous Optimization**: Regular monitoring enables Data Centres to adjust operations for optimal PUE.
  - **Reduced Carbon Footprint**: By improving PUE, Data Centres reduce their overall energy consumption.
  - **Industry Recognition**: An optimized PUE is a well-respected performance indicator in the sector.

3.1.5 ASHRAE - Cooling and Air Conditioning Standards

- **Objective**: Optimize cooling and air conditioning systems in data centres by leveraging ASHRAE's environmental classes (A1–A4), which define allowable ranges for temperature and humidity. These classes guide the creation of efficient and reliable operating conditions for IT equipment:
  - Class A1: Most restrictive, suitable for highly controlled environments.
  - Class A4: Allows for the widest range of temperature and humidity, enabling flexibility and cost efficiency, particularly valuable in warm climates.
- **Description**: ASHRAE provides thermal guidelines tailored to Data Centres' specific needs. These standards include air flow management, humidity and temperature control, and cooling equipment optimization.
- **Benefits**:
  - **Cooling Cost Reduction**: Optimized practices lower the energy needed for cooling, a significant expense.
  - **Extended Equipment Lifespan**: Optimal temperature and humidity control reduce the risk of IT equipment failure and wear.
  - **Adaptation to Warm Climates**: These standards are particularly useful for Data Centres in tropical climates like Uganda's.
  - **Flexible Application**: ASHRAE standards can be applied to existing infrastructures, enabling improvements in cooling systems.

3.1.6 BREEAM (Building Research Establishment Environmental Assessment Method)

- **Objective:** Evaluate the environmental performance of Data Centres throughout their lifecycle, from design to operation.
- **Description:** BREEAM is a rigorous sustainable construction framework, covering criteria like energy, water management, materials, and waste. It includes an annex for Data Centres, assessing environmental performance across multiple categories.
- **Benefits**:
  - **Lifecycle Adaptability:** BREEAM assesses sustainable practices at each phase, encouraging continuous improvement.
  - **International Recognition:** BREEAM is a well-recognized sustainability standard, attracting investors and enhancing certified infrastructure competitiveness.
  - **Innovation Incentives:** BREEAM encourages new technologies and sustainable practices, promoting creativity.

- **Support for National Sustainability Goals:** By meeting BREEAM standards, Data Centres support Uganda's sustainability commitments.

3.1.7 EU Code of Conduct for Data Centres

- **Objective:** Provide a set of best practices for energy efficiency and reducing Data Centres' environmental impact.
- **Description**: The European Code of Conduct for Data Centres is a practical framework offering energy efficiency recommendations without requiring formal certification. It addresses topics like IT equipment management, temperature optimization, and resource management.
- **Benefits**:
  - **Progressive Energy Improvements**: This code allows sustainable practices to be implemented without the requirements of formal certifications.
  - **Reduced Cost**: Unlike full certifications, the Code of Conduct is more economical while providing energy efficiency gains.
  - **Adapted to Existing Infrastructure**: It suits Data Centres aiming for sustainable practices without major renovations.
  - **Flexible Implementation**: Easily adaptable and scalable, aligned with Uganda's available resources.

3.1.8 Guide ITU et Banque Mondiale pour les Data Centres Verts

- **Objective**: Provide comprehensive recommendations for sustainable and eco-friendly Data Centre management throughout the lifecycle.
- **Description**: Developed by the ITU and the World Bank, this guide proposes directives to minimize Data Centres' environmental impact from design to operation. It covers areas such as location, modularity, renewable energy integration, and resource management.
- **Benefits**:
  - **Holistic Approach**: This guide offers recommendations for each lifecycle stage, ensuring sustained durability.
  - **Alignment with SDGs**: Recommended practices support international sustainability goals.
  - **Climate Resilience**: By promoting resilient design and operational practices, this guide helps Data Centres adapt to climate impacts.
  - **Local Applicability**: This guide proposes practices tailored for developing countries, facilitating adoption in Uganda.

Figure 27: Illustration showing the phases of application for key certifications throughout the lifecycle of green Data Centres in Uganda

Certification/ Label	Data Centre Lifecycle			Description
	Design	Construction	Operation	
ISO 14 001	√	√	√	Environmental management to reduce ecological impact at each stage
ISO 50 001	√		√	Continuous optimization of energy consumption

(continued)

Certification/ Label	Data Centre Lifecycle			Description
	Design	Construction	Operation	
LEED	√	√		Ecological design and construction
Green Grid (PUE)			√	Measurement of the energy efficiency of the Data Centre
ASHRAE	√		√	Cooling standards for improved thermal management
BREEAM	√	√	√	Comprehensive sustainability assessment, enhances ecological reputation
EU Code of Conduct	√		√	Practical recommendations to improve energy efficiency
Guide ITU	√	√	√	Recommendations for a sustainable and resilient lifecycle

Figure 28: Key Themes Addressed by Green Data Centre Certifications

Certification/ Guide	ISO 14001	ISO 50001	LEED	PUE (Green Grid)	ASHRAE	BREEAM	EU Code of Conduct for Data Centres	Guide ITU/ World Bank
Environment	√		√		√	√	√	√
Biodiversity			√			√		
Climate Change	√	√	√			√	√	√
Energy		√	√	√	√	√	√	√
Resource Management	√		√			√		√
Regulation	√	√						√
Cost and Efficiency	√	√	√	√	√	√	√	√
Well-being and Resilience			√		√	√	√	√

3.2 Comparison of Certifications and Applicability in Uganda

Selecting certifications suited for green Data Centres in Uganda involves considering multiple criteria, such as the lifecycle phase they apply to (design, construction, operation), their cost, ease of implementation, and environmental impact. In Uganda, where energy access can be costly and climate resilience is critical, certain standards offer specific advantages.

3.2.1 Comparison Criteria

The certifications and labels are evaluated according to the following criteria:

1. **Phase of Application**: Does the certification apply to design, construction, or operation?
2. **Ease of Application**: Is it compatible with local infrastructure and resources? This includes the availability of local experts, the complexity of requirements, and the time needed to obtain certification.
3. **Implementation Cost**: This factor depends on the size of the infrastructure and required audits.
4. **Adaptability to Ugandan Context**: This criterion assesses each certification's relevance to the local energy and environmental context.

3.2.2 Applicability Analysis of Certifications for Data Centres in Uganda

3.2.2.1 ISO 14001 - Environmental Management Systems

- **Applicability**: This standard applies to all phases of the Data Centre lifecycle, offering structured management of environmental impacts. In Uganda, it is especially relevant for helping Data Centres establish ecological management practices, reduce waste, and optimize natural resource use. ISO 14001 is also readily applicable to existing infrastructures and can adapt to local regulations, essential in a developing context.
- **Specific Advantages**:
  - **Regulatory Compliance**: Helps Data Centres adhere to local and international environmental standards.
  - **Attraction of Green Funding**: Compliance with ecological standards can attract green funding to support sustainable infrastructure projects.
  - **Resource Optimization**: Guides the efficient use of water, energy, and materials, reducing operational costs and minimizing waste.

3.2.2.2 ISO 50001 - Energy Management Systems

- **Applicability**: ISO 50001 specifically targets the operational phase. It supports continuous energy management, a crucial issue in Uganda, where energy costs are high and infrastructure may be limited. This standard is also adaptable to existing infrastructures, facilitating its integration into already functioning centres.
- **Specific Advantages**:
  - **Reduction in Energy Costs**: Optimizing energy management can significantly cut down electricity expenses.
  - **Reduced Carbon Footprint**: Limiting energy consumption directly decreases CO_2 emissions, aligning with Uganda's climate goals.
  - **Continuous Improvement**: ISO 50001 includes monitoring and audit mechanisms that promote ongoing energy efficiency improvements, essential for adapting to increasing demand.

3.2.2.3 LEED - Leadership in Energy and Environmental Design

- **Applicability**: Particularly suited for new Data Centre projects, LEED may be more challenging to apply to existing infrastructure due to its high cost and strict requirements. In Uganda, LEED certification is ideal for Data Centres aiming to stand out in terms of sustainability and enhance their brand image among international investors.

- **Specific Advantages**:
  - **Global Recognition**: LEED certification increases the visibility of Data Centres globally, attracting investors and clients.
  - **Integrated Sustainability**: LEED promotes sustainable design and construction practices, considerably reducing environmental impacts, especially in energy and water use.
  - **Improved Working Conditions**: Ensuring high-quality materials and indoor air quality, this certification benefits employees' health and reduces health risks.

3.2.2.4 PUE - Power Usage Effectiveness

- **Applicability**: PUE is extremely valuable in Uganda, where energy infrastructure can be costly. This indicator can be easily applied in the operational phase, allowing Data Centre managers to continuously monitor energy performance. PUE is flexible and applicable to both new and existing facilities, making it easier to adopt.
- **Specific Advantages**:
  - **Simplified Energy Monitoring**: PUE enables efficient tracking of energy performance and quick identification of waste sources.
  - **Cost Optimization**: Improving energy efficiency can reduce operational costs, which is crucial in Uganda's context.
  - **Continuous Improvement**: Data collected through PUE supports real-time adjustments, optimizing energy efficiency throughout operations.

3.2.2.5 ASHRAE - Cooling and Air Conditioning Standards

- **Applicability**: ASHRAE is essential in warm climates like Uganda's, where thermal management is a major issue for durability and equipment lifespan. These standards apply to the design and operational phases of cooling systems, ensuring that Data Centres maintain optimal conditions for server operation.
- **Specific Advantages**:
  - **Reduced Cooling Costs**: ASHRAE helps optimize cooling systems, reducing energy consumption and associated costs.
  - **Equipment Preservation**: Maintaining ideal temperature and humidity lowers the risks of failures and wear on IT equipment.
  - **Climate Adaptation**: ASHRAE provides thermal solutions tailored to local climate conditions, enhancing the resilience of Ugandan Data Centres.

3.2.2.6 BREEAM - Building Research Establishment Environmental Assessment Method

- **Applicability**: BREEAM is especially suitable for internationally funded projects in Uganda. Although costly, it measures sustainability at every lifecycle stage and is ideal for new Data Centres seeking international recognition.
- **Specific Advantages**:
  - **Attracts International Financing**: BREEAM's global reputation attracts investors seeking environmentally-friendly infrastructure.
  - **Sustainability and Innovation**: BREEAM encourages the use of sustainable, innovative technologies, allowing Data Centres to stand out in terms of innovation.

- **Supports National Sustainability Goals**: By adopting BREEAM, Data Centres actively contribute to both national and global sustainability goals, enhancing their credibility.

3.2.2.7 EU Code of Conduct pour les Data Centres

- **Applicability:** Although not a formal certification for Data Centres outside Europe, the European Code of Conduct can serve as a useful reference for adopting sustainable energy practices in Uganda. Its recommendations can be easily adapted to existing infrastructure, offering a base for energy savings without formal certification.
- **Specific Advantages**:
  - **Low Implementation Cost:** Unlike full certifications, following the Code of Conduct is cost-effective, allowing Data Centres to implement green practices without certification constraints.
  - **Adaptable Practices:** The Code's recommendations can be easily integrated into existing facilities, helping Ugandan Data Centres improve energy performance.
  - **Gradual Improvement:** It enables Data Centres to progressively work towards energy efficiency goals affordably, facilitating a shift toward more sustainable practices.

3.2.2.8 ITU and World Bank Guide for Green Data Centres

- **Applicability**: This guide is specifically designed for developing countries, making it a particularly suitable resource for the needs of Data Centres in Uganda. It covers each phase of the lifecycle, offering recommendations for sustainable and resilient management, especially in contexts with limited infrastructure and resources.
- **Specific Advantages**:
  - **Integrated Sustainability Approach**: The guide provides comprehensive recommendations for all stages, from design to operation, enabling a coherent and adaptable long-term sustainability strategy.
  - **Climate Resilience**: By encouraging resilient construction and management practices, this guide helps Data Centres adapt to local climate conditions and the specific infrastructure challenges faced by tropical countries like Uganda.
  - **Environmental Impact Reduction**: The ITU and World Bank guide places strong emphasis on energy efficiency, water management, and the use of sustainable materials, helping to minimize environmental impacts at every lifecycle stage.
  - **Adaptation to Local Realities**: Specifically oriented towards developing countries, this guide takes into account budgetary and infrastructural constraints, offering practical and applicable solutions to maximize ecological performance with limited resources.
  - **Support for Sustainable Development Goals (SDGs)**: By following the guide's recommendations, Ugandan Data Centres actively contribute to the SDGs related to sustainability, emissions reduction, and resource optimization.

Figure 29: Evaluation of Certifications for Green Data Centre Implementation

Certification / Label	Phase(s) of Application	Ease of Application	Cost	Adaptability for Uganda
ISO 14001	Design, Construction, Operation	High	Medium	Ideal for structuring environmental management and ensuring regulatory compliance.

(continued)

Certification / Label	Phase(s) of Application	Ease of Application	Cost	Adaptability for Uganda
ISO 50001	Operation	Medium	Medium	Useful for reducing energy costs and improving efficiency where energy is expensive.
LEED	Design, Construction	Medium	High	Suitable for new projects; enhances the green reputation of facilities.
PUE (Green Grid)	Operation	Very High	Low	Effective for optimizing energy use where energy access is limited.
ASHRAE	Design, Operation	Medium	Medium	Essential for thermal management in hot climates, extending equipment lifespan.
BREEAM	Design, Construction, Operation	Medium	High	Recommended for internationally financed projects; strengthens environmental recognition.
EU Code of Conduct	Design, Operation	High	Low	A flexible guide for energy practices, although not a formal certification outside Europe.
ITU / World Bank Guide	Design, Construction, Operation	High	Variable	Offers resilient, holistic practices for infrastructures in developing countries.

3.2.3 Prioritization of Certifications for Data Centres in Uganda

The following prioritization framework has been developed to guide the implementation of certifications and guidelines for both new and existing data centres in Uganda. The approach is designed to balance ease of implementation, cost, and relevance to Uganda's context, ensuring that each data centre can align with sustainability goals and operational efficiency. The certifications are categorized into three levels of priority (P1, P2, P3), reflecting their importance and feasibility depending on the data centre's lifecycle stage.

3.2.3.1 For New Data Centres

- **P1 (High Priority): Foundational Certifications and Guidelines**
  - **ISO 14001**: Establishes robust environmental management from the design stage.
  - **ITU/World Bank Guide**: Flexible, practical, and tailored for developing countries like Uganda.

- **PUE (Green Grid)**: A low-cost, measurable metric to ensure energy-efficient design.

- **P2 (Medium Priority): Supporting Standards for Enhanced Performance**
  - **ASHRAE Guidelines**: Critical for designing cooling systems tailored to Uganda's climate but remains a guideline, not a formal certification.
  - **LEED**: Enhances sustainability reputation and attracts international funding but requires significant resources.
  - **EU Code of Conduct (CoC)**: Useful for energy efficiency, but its European focus may require adaptation.
- **P3 (Low Priority): Advanced or Specialized Certifications**
  - **BREEAM**: Provides international recognition but is costly and complex to implement.
  - **ISO 50001**: Focused on energy management, suitable for operational phases rather than design.

3.2.3.2 For Existing Data Centres

- **P1 (High Priority): Practical and Immediate Impact**
  - **ISO 14001**: Enables environmental improvements and compliance during operations.
  - **ITU/World Bank Guide**: Offers practical, adaptable solutions for improving sustainability in existing facilities.
  - **PUE (Green Grid)**: Optimizes energy efficiency with minimal cost and complexity.
- **P2 (Medium Priority): Operational Efficiency Improvements**
  - **ASHRAE Guidelines**: Helpful for optimizing cooling systems and extending equipment lifespan but remains non-binding.
  - **EU Code of Conduct (CoC)**: A flexible and low-cost option for improving operational energy efficiency.
  - **ISO 50001**: Supports long-term energy management, requiring moderate investment.
- **P3 (Low Priority): Resource-Intensive or Specialized Standards**
  - **LEED**: Valuable for significant renovations but less applicable without major upgrades.
  - **BREEAM**: Ideal for large retrofitting projects funded by international organizations but demanding in cost and resources.

This prioritization framework provides a clear pathway for data centres in Uganda to adopt and implement sustainability certifications and guidelines. By focusing first on high-priority (P1) certifications such as ISO 14001, ITU Guide, and PUE, data centres can achieve immediate and impactful improvements in environmental and operational performance. Medium- (P2) and low-priority (P3) certifications, such as LEED and BREEAM, can be pursued as resources and operational maturity grow, ensuring a sustainable and scalable approach to green data centre development.

The following chapters outline a comprehensive approach to designing, constructing, and operating green Data Centres in Uganda. By applying ecological standards to each phase of their lifecycle, these centres aim to reduce their carbon footprint, improve energy efficiency, and promote responsible resource management.

Through sustainable design strategies, environmentally-friendly construction practices, and optimized operational and maintenance management, these standards establish a foundation for resilient digital infrastructure that respects the local ecosystem. By adopting these guidelines, Data Centres in Uganda can not only meet the growing demands of digitization but also make a meaningful contribution to the country's environmental and sustainability goals.

4 Ecological Design Standards

4.1 Criteria For Sizing And Location

Optimal sizing ensures data centre resources align with current needs while remaining scalable to meet future growth. This approach balances cost-efficiency, environmental impact, and operational effectiveness.

4.1.1 Optimal Sizing

4.1.1.1 Assess Current Needs and Future Growth

- Evaluate immediate requirements, including storage capacity and processing power, based on current user demand.
- Use predictive analytics to anticipate growth in digital service adoption over a 5-10 year horizon, factoring in trends like mobile penetration and cloud computing.

4.1.1.2 Prevent Oversizing

- Avoid unnecessary upfront investment and energy consumption by designing to current needs while planning for scalable expansion.
- **Example**: Modular designs like the Facebook Data Centre in Luleå, Sweden, reduce initial costs and ecological impacts by enabling capacity to grow in stages.

4.1.1.3 Modular and Flexible Design

- Modular architecture allows incremental additions, aligning capacity with real-time demand growth without major disruptions.
- **Application in Uganda**: Modular systems are especially critical in developing markets, where demand forecasting can be unpredictable, ensuring cost and resource optimization.

4.1.1.4 Plan for Redundancy

- Include redundancy in power, cooling, and storage to ensure uptime during failures without overbuilding core systems.
- Address local challenges like Uganda's grid reliability and power outages by integrating resilient backup systems.

4.1.1.5 Adapt to Local Market Needs

- Design facilities that consider cost constraints and market demands in Uganda, balancing infrastructure affordability with support for industries like banking, telecom, and government.

4.1.1.6 Benefits of Optimal Sizing

- **Cost Efficiency**: Reduces capital and operational expenditures by avoiding unnecessary infrastructure investments.

- **Energy and Resource Savings**: Minimizes energy use and environmental impact by starting small and expanding only when needed.
- **Scalability**: Ensures flexibility for future growth with modular designs.
- **Reliability**: Provides redundancy to ensure continuous operation despite infrastructure challenges.

4.1.1.7 Recommendations for Uganda

1. **Adopt Modular Systems**: Build a core system with scalable modules for future expansion.
2. **Use Data-Driven Projections**: Rely on digital adoption forecasts to size initial infrastructure.
3. **Focus on Energy-Efficient Solutions**: Deploy systems that align with Uganda's ecological and economic goals.

Figure 30: Modular Data Centre design

4.1.2 Location Selection

The location of a data centre is a critical factor influencing its performance, sustainability, and cost efficiency. A strategic location can leverage natural and infrastructural advantages to optimize energy use, ensure connectivity, and enhance climate resilience, all while minimizing operational costs and environmental impact.

4.1.2.1 Proximity to Renewable Energy Sources

- **Leverage Local Resources**:
  - Data centres should be located near renewable energy sources like hydroelectric power (e.g., Karuma, Nalubaale dams) or solar energy (e.g., Karamoja region). This reduces reliance on fossil fuels and minimizes transmission losses.
  - Solar-rich regions can integrate photovoltaic systems with battery storage to ensure sustainable energy availability.

Google's data centres in Europe prioritize locations near renewable energy facilities to achieve carbon neutrality.

- o **Application in Uganda:** Build data centres close to hydroelectric facilities or in areas with high solar potential, using storage systems to manage intermittency.

4.1.2.2 Access to Reliable Connectivity

- **Proximity to Fiber Optic Hubs**:
    - o Data centres should be located near major internet exchange points to ensure high-speed, low-latency connectivity. In Uganda, hubs in Kampala and Entebbe offer the most reliable network infrastructure.
- **Innovative Connectivity Solutions**:
    - o Use Broadband over Power Lines (BPL) to expand connectivity to rural or underserved areas.
    - o **Example**: South Africa has successfully tested BPL to integrate high-voltage power lines with data transmission networks.
- **Application in Uganda:** Combine proximity to fiber hubs with BPL technology to extend connectivity across regions while leveraging existing infrastructure.

4.1.2.3 Climate and Cooling Efficiency

- **Natural Cooling Potential**:
    - o Cooler regions like the Western Highlands (e.g., Kabale) offer natural advantages by reducing mechanical cooling requirements, lowering energy consumption.
    - o Incorporate free cooling, which uses cool night air to maintain server temperatures.
- **Climate Considerations**:
    - o Avoid regions prone to extreme heat or humidity, which increase cooling demands.

4.1.2.4 Logistical Accessibility

- **Ease of Maintenance and Operations**:
    - o Proximity to transport hubs like Entebbe International Airport or major highways ensures efficient delivery of equipment, rapid maintenance, and reduced logistical costs.
    - o Urban centres such as Kampala offer well-established infrastructure and skilled labor pools.

4.1.2.5 Climate Resilience

- **Flood and Disaster Risk Reduction**:
    - o Avoid low-lying or flood-prone areas to protect critical infrastructure. Elevation or natural barriers can mitigate risks associated with extreme weather events.

Green Mountain Data Centre in Norway uses natural caves for protection and thermal efficiency.

- **Application in Uganda**:

- o Conduct climate risk assessments to identify regions with minimal vulnerability to floods, landslides, or extreme heat.

4.1.2.6 Benefits of Strategic Location Selection

- **Cost Efficiency**: Reduces energy and operational costs by leveraging local advantages such as renewable energy and cooler climates.
- **Improved Connectivity**: Ensures faster data transmission and lower latency through proximity to fiber hubs.
- **Environmental Sustainability**: Minimizes carbon footprint by using renewable energy and natural cooling.
- **Operational Stability**: Enhances resilience to climate and logistical challenges, ensuring uninterrupted service.

4.1.2.7 Recommended Prioritization for Location Selection

1. **Connectivity and Logistical Access**
   - o Select locations near fiber hubs, transport routes, and skilled labor to optimize network performance and operational efficiency.
2. **Renewable Energy Proximity**
   - o Position data centres near hydroelectric or solar facilities to ensure sustainable energy supply and reduce emissions.
3. **Favorable Climate**
   - o Choose cooler regions or integrate free cooling techniques to reduce energy consumption.
4. **Resilience to Climate Risks**
   - o Ensure the site is secure from natural disasters, with infrastructure designed for long-term durability.

4.2 Sustainable Building Design

The architecture of a data centre serves as the foundation for its environmental impact, operational efficiency, and scalability. By integrating sustainable construction materials, passive cooling techniques, and resource-efficient systems, data centres can minimize their ecological footprint while ensuring reliable performance. This section focuses on architectural strategies specific to the building structure.

4.2.1 Sustainable Construction Materials

The materials used in the construction of a data centre play a critical role in its environmental performance. Incorporating low-carbon, thermally efficient, and locally sourced materials can significantly reduce emissions and improve operational efficiency.

- **Compressed Earth Bricks (Hydraform):** These locally manufactured bricks are produced with minimal energy, reducing embodied carbon by up to 30 per cent compared to traditional fired bricks. Their natural thermal properties help stabilize indoor temperatures in warm climates like Uganda's.

- Recycled Concrete: Utilizing concrete from old structures reduces reliance on new material production, which is highly carbon-intensive. For a 1,000-square-meter facility, this can save approximately 120 metric tons of CO_2.
- High-Performance Insulation: Advanced insulation materials, such as aerogels or rigid foam panels, prevent heat exchange and maintain stable indoor temperatures. Efficient insulation can lower cooling energy use by 25–30 per cent.
- Reflective Roofs: Coatings or materials with high solar reflectance reduce heat absorption, cutting cooling loads by up to 50 per cent. This can save up to 200,000 kWh annually for a 10,000-square-meter facility.

4.2.2 Passive Cooling Techniques

Passive cooling methods use architectural strategies to regulate indoor temperatures without relying on energy-intensive systems. These techniques provide an environmentally friendly way to control heat within the facility.

- **Vegetated Facades:** Green walls act as natural insulators, reducing heat transfer and lowering indoor temperatures. They can decrease wall surface temperatures by up to 10°C, reducing cooling loads by approximately 20 per cent. For a mid-sized data centre, this could save 50,000 kWh annually.
- **Hygrothermal Materials for Thermal Regulation:** Materials such as rammed earth or thermally treated wood help stabilize indoor temperatures by managing heat and moisture. These materials are particularly effective in warm, humid climates.

4.2.3 Resource Efficiency

Resource-efficient architectural design is critical for minimizing the environmental footprint of data centres. Strategies that focus on water and energy reuse ensure long-term sustainability.

4.2.3.1 Water Management Systems:

- **Rainwater Harvesting:** Collect and store rainwater for non-potable uses, such as irrigation and cleaning, to reduce municipal water reliance. This can lower water consumption by up to 30 per cent.
- **Closed-Loop Cooling Systems:** Design cooling systems to recycle water, minimizing overall water usage.

4.2.3.2 Heat Recovery Systems:

- Heat recovery systems capture the waste heat generated by IT equipment and repurpose it for secondary uses, such as heating nearby residential buildings, industrial processes, or agricultural activities. This approach significantly reduces the overall energy footprint of the data centre by turning a byproduct into a valuable resource. For example, a 1 MW data centre can recover up to 2,600 MWh of heat annually, cutting external heating costs by 50 per cent. In Uganda, these systems are especially beneficial in urban areas where waste heat can be efficiently redirected to support district heating, industrial drying, or other localized energy needs. This not only minimizes energy waste but also contributes to the sustainability of surrounding communities.

4.2.3.3 Benefits of Sustainable Building Design

- Energy Efficiency: Reduced energy consumption through advanced insulation, passive cooling, and heat recovery systems.

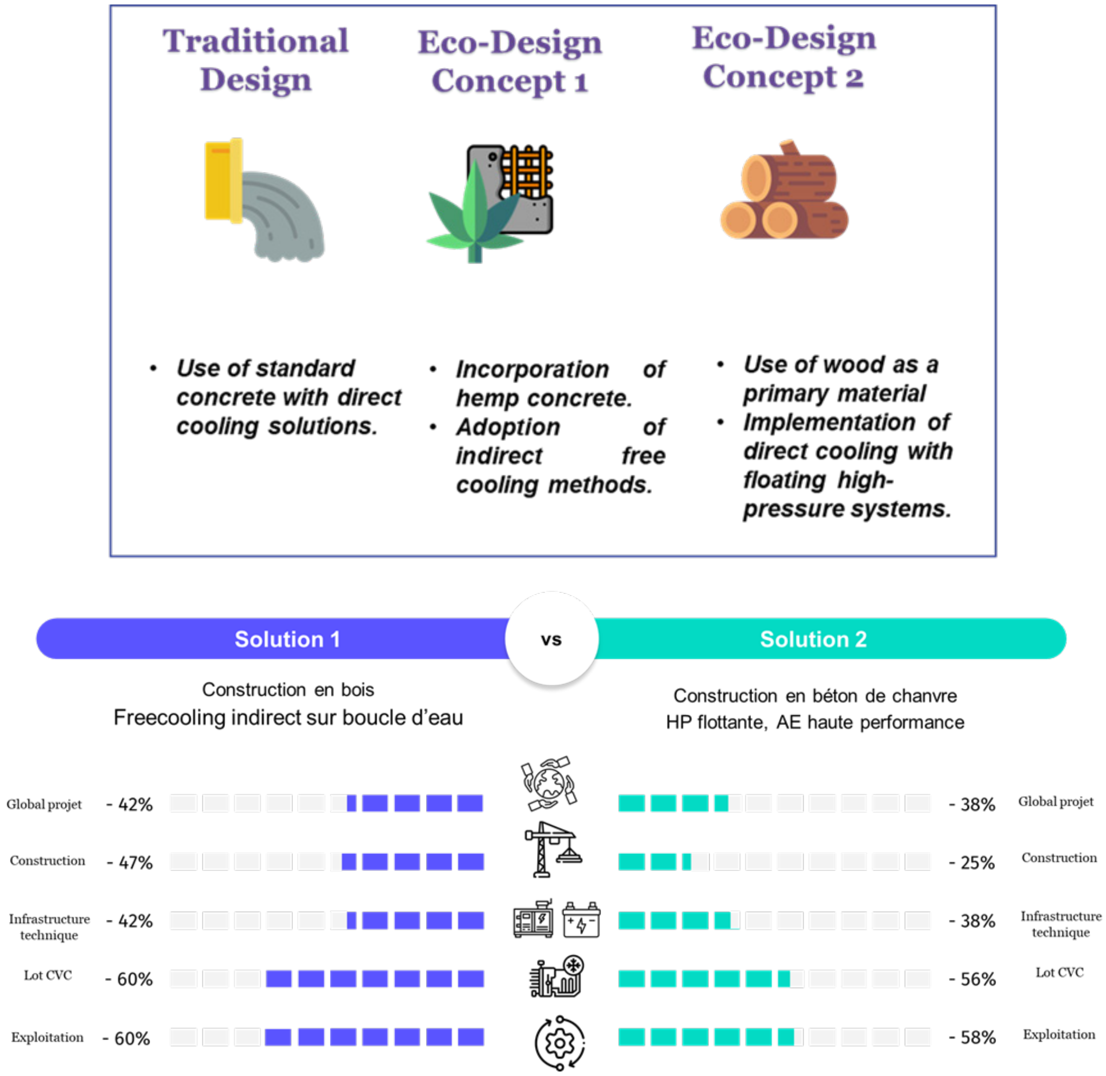
- Carbon Footprint Reduction: Use of low-carbon materials and efficient resource management minimizes environmental impact.
- Cost Savings: Lower operational expenses from decreased energy and water usage, with additional savings from heat recovery.
- Local Economic Support: Promotes regional industries through locally sourced materials and reduced transportation emissions.
- Resilience: Climate-adaptive designs protect against environmental risks like floods and extreme weather.
- Scalability: Flexible building structures accommodate future growth and technological upgrades.

4.2.3.4 Recommended Prioritization for Sustainable Building Design

1. **Connectivity and Logistical Access**
   - Select locations near fiber hubs, transport routes, and skilled labor to optimize network performance and operational efficiency.
2. **Renewable Energy Proximity**
   - Position data centres near hydroelectric or solar facilities to ensure sustainable energy supply and reduce emissions.
3. **Favorable Climate**
   - Choose cooler regions or integrate free cooling techniques to reduce energy consumption.
4. **Resilience to Climate Risks**
   - Ensure the site is secure from natural disasters, with infrastructure designed for long-term durability.

Figure 31: Structural Options for Sustainable Data Centre Construction

Figure 32: Comparing Traditional and Eco-Design Approaches for Green Data Centres: Material Choices and Cooling Efficiency



4.3 Technical Equipment

Technical equipment in data centres is central to ensuring efficient, reliable, and sustainable operations. The proper selection, design, and integration of systems such as cooling, power distribution, and fire protection significantly impact energy consumption, operational costs, and the environmental footprint of the facility. This section outlines key technical equipment components, their functions, and their contribution to energy efficiency and sustainability.

4.3.1 Cooling Systems

Cooling is one of the most energy-intensive functions in a data centre, often accounting for 30–40 per cent of total energy consumption. The adoption of innovative and efficient cooling technologies can significantly reduce energy use and carbon emissions.

4.3.1.1 Direct Liquid Cooling (DLC)

Liquid cooling systems circulate coolants directly to IT components, such as CPUs and GPUs, to remove heat efficiently at the source. DLC systems eliminate heat transfer inefficiencies inherent in air-based systems.

- **Energy Benefits**: Reduces cooling energy consumption by 20–30 per cent, saving up to 260,000 kWh annually for a 1 MW facility.
- **Application in Uganda**: DLC is particularly beneficial for high-density data centres in urban areas like Kampala, where energy efficiency and compact designs are critical.

4.3.1.2 Adiabatic Cooling:

Adiabatic cooling systems rely on water evaporation to cool the incoming air, significantly reducing the energy needed for mechanical cooling.

- **Energy Benefits:** Reduces cooling energy use by up to 90 per cent, saving approximately 788,000 kWh annually for a 1 MW facility.
- **Application in Uganda:** Suitable for drier regions such as Karamoja, where air dryness improves cooling efficiency.

4.3.1.3 Centralized Cooling Units:

Centralized systems optimize cooling by serving multiple facility areas with a shared system, reducing redundancy and increasing efficiency.

- **Energy Benefits:** Improve cooling efficiency by 5–10 per cent, saving 50,000–100,000 kWh annually for mid-sized facilities.
- **Application in Uganda:** Best suited for large data centres or industrial hubs, where centralized control reduces costs and operational complexity.

4.3.1.4 Low-GWP Refrigerants:

Refrigerants with a low Global Warming Potential (GWP), such as HFO-1234yf or R-32, minimize the environmental impact of cooling systems while maintaining high performance.

- **Environmental Benefits:** Reduce greenhouse gas emissions by up to 90 per cent compared to traditional refrigerants like R-410A.
- **Application in Uganda:** Aligns with international environmental standards and is suitable for all data centres aiming to reduce their carbon footprint.

4.3.1.5 Direct Expansion (DX) Cooling Systems:

DX cooling uses refrigerants to cool air directly in the IT room, offering high efficiency in compact systems.

- **Energy Benefits:** Ideal for smaller data centres, DX systems optimize energy use with precise cooling.
- **Application in Uganda:** Suitable for smaller facilities or modular data centres requiring efficient, localized cooling.

4.3.1.6 Geothermal Cooling:

Geothermal systems use the stable underground temperature to dissipate heat. A fluid circulates through underground pipes to transfer heat away from the data centre.

- **Energy Benefits:** Reduces cooling energy use by up to 50 per cent, saving 400,000 kWh annually for a 1 MW facility.
- **Application in Uganda:** Effective in regions with consistent underground temperatures, particularly in urban areas like Kampala.

4.3.1.7 Free Cooling:

Free cooling leverages cool outdoor air to regulate the temperature of IT equipment, bypassing traditional mechanical cooling systems.

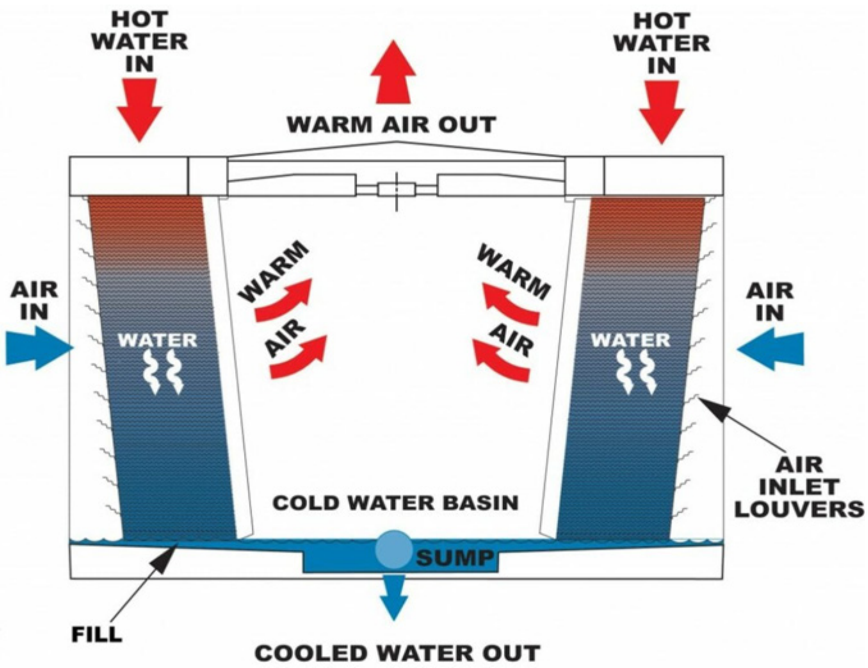
- **Energy Benefits:** Reduces cooling energy use by up to 30 per cent, depending on climate and facility design.
- **Application in Uganda:** Most applicable in cooler regions such as Uganda's Western Highlands, where nighttime temperatures can offset cooling demands.

4.3.1.8 Free Chilling:

Free chilling uses natural cold water sources, such as rivers or lakes, to cool data centres directly.

- **Energy Benefits:** Completely eliminates mechanical cooling during favorable conditions, reducing energy consumption by up to 70 per cent.
- **Application in Uganda:** Potentially suitable for data centres located near natural water sources like Lake Victoria, where water temperature is sufficiently low for effective chilling.

Figure 33: Modular Data Centre design



4.3.2 Power Distribution Systems

Electrical systems in data centres ensure the continuous and reliable delivery of power to IT equipment, even during outages or fluctuations. Efficient power infrastructure reduces energy losses, supports renewable integration, and ensures sustainability. Below are the critical components of electrical systems, their functions, energy benefits, and specific applications in Uganda.

4.3.2.1 High-Efficiency Inverters

High-efficiency inverters, also known as converters, transform direct current (DC) from sources like batteries or solar panels into alternating current (AC) used by IT equipment. Modern inverters achieve remarkable energy conversion rates, reducing operational losses.

- **Energy Benefits:** High-efficiency inverters achieve conversion efficiencies of up to **98 per cent**, reducing energy losses by 20–30 per cent compared to older systems. For a 5 MW data centre, this improvement can save approximately **131,000 kWh annually**, lowering both costs and emissions.
- **Application in Uganda:** These systems are critical in areas with variable power quality, such as Kampala and Entebbe, where fluctuations can disrupt operations. By ensuring efficient power conversion, these inverters enhance reliability and reduce dependency on grid energy.

4.3.2.2 Sustainable Backup Power Systems

Backup power systems are essential for ensuring uninterrupted operations during power outages. Sustainable solutions prioritize low-carbon technologies while maintaining reliability.

- **HVO Generators**:

  Generators powered by Hydrotreated Vegetable Oil (HVO), a renewable fuel derived from organic materials, offer a cleaner alternative to traditional diesel generators.

  - **Energy Benefits:** Reduce **CO_2 emissions by up to 90 per cent**, as well as particulate matter and NOx emissions, compared to conventional diesel.
  - **Application in Uganda**:
    - Ideal for urban areas like Kampala, where air pollution is already a concern.
    - Increases resilience in regions with frequent grid outages, providing reliable, low-emission backup power.
- **Energy Storage Batteries**:

  Lithium-ion and other advanced batteries store electricity from renewable sources or the grid, ensuring continuous power during outages.

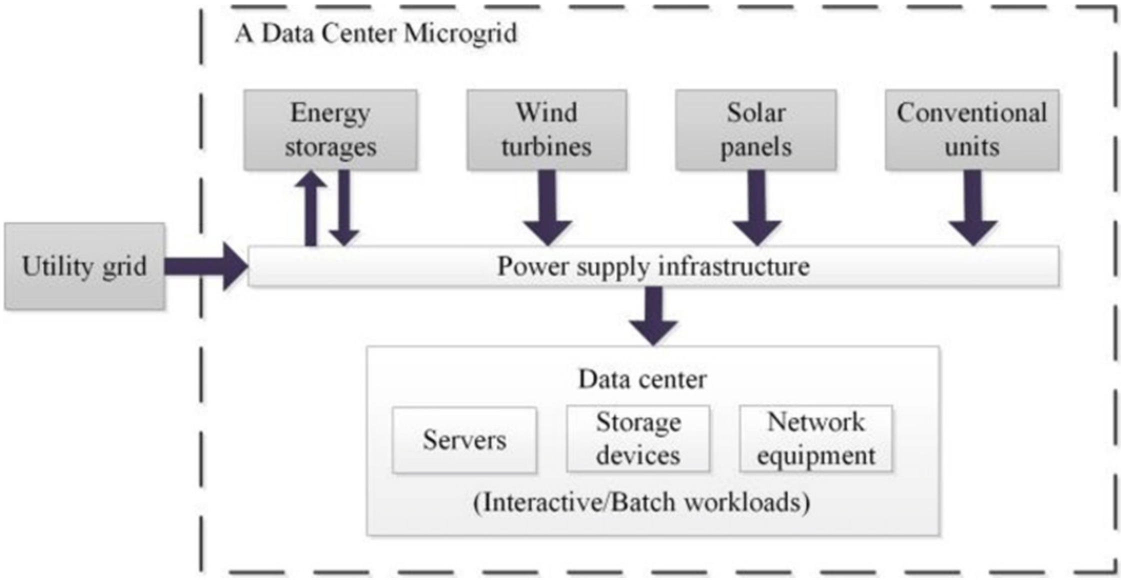
  - **Energy Benefits:** Reduce reliance on fossil-fuel generators by storing energy for later use. A 1 MW system with energy storage can save thousands of liters of diesel annually, translating to significant emission reductions.
  - **Application in Uganda**:
    - Particularly effective in rural areas or regions with renewable energy sources, such as Karamoja, where solar power can be stored for nighttime operations.
    - Offers a sustainable alternative to diesel reliance in off-grid or hybrid power setups.

- **Microgrids and Cogeneration**:

  Microgrids integrate multiple energy sources (e.g., solar, wind, hydroelectric) with energy storage systems, enabling localized, independent energy generation. Cogeneration systems simultaneously produce electricity and useful heat from the same fuel source, maximizing resource efficiency.

  - **Energy Benefits**:
    - Increase self-sufficiency by reducing reliance on national grids.
    - Cogeneration systems improve fuel utilization efficiency by up to 70 per cent, compared to 30–40 per cent for traditional generators.
  - **Application in Uganda**:
    - Microgrids are ideal for rural or remote areas, such as Karamoja or districts far from major urban centres, where grid access is unreliable or absent.
    - Cogeneration systems are particularly beneficial for large-scale facilities in industrial zones, ensuring maximum efficiency of fuel use.

Figure 34: Microgrid Architecture for Energy Management in a Data Centre



4.3.3 Fire Suppression Systems

Fire suppression systems are critical for safeguarding IT infrastructure and ensuring operational continuity in data centres. Selecting the right system balances effectiveness, environmental sustainability, and operational needs. Below are key fire suppression technologies and their applications in Uganda.

4.3.3.1 Inert Gas Suppression Systems

Inert gas systems extinguish fires by reducing oxygen levels to below the combustion threshold, using gases like nitrogen or argon. These systems are residue-free and safe for sensitive equipment.

- **Benefits:** Avoids water damage, zero emissions, and minimal recovery costs.

- **Application in Uganda:** Ideal for semi-arid or rural areas like Karamoja, where water scarcity is a concern.

4.3.3.2 Water Mist Systems

Water mist systems use fine droplets to cool fires and displace oxygen, offering effective suppression with minimal water usage.

- **Benefits:** Consumes **80–90 per cent less water** than traditional sprinklers, reducing damage to IT equipment and conserving resources.
- **Application in Uganda:** Ideal for urban data centres in Kampala, where protecting sensitive IT systems and minimizing downtime are critical.

4.3.3.3 Advanced Fire Detection Systems

These systems use sensors to detect fire at an early stage, triggering alarms and suppression systems automatically.

- **Benefits:** Early intervention minimizes damage, recovery costs, and operational disruptions.
- **Application in Uganda:** Valuable for large facilities requiring constant monitoring to ensure rapid localized response.

4.3.4 Recommended Prioritization for Technical Equipment

4.3.4.1 Cooling Systems (CVC)

1. **Adiabatic Cooling**

Adiabatic cooling achieves up to 90 per cent energy savings, making it highly impactful for reducing energy consumption and operational costs. It is particularly effective in drier regions like Karamoja, where lower humidity levels enhance performance. However, it requires consistent water availability, though minimal compared to traditional systems.

2. **Direct Liquid Cooling (DLC)**

DLC reduces cooling energy consumption by **20–30 per cent**, making it particularly effective for high-density urban data centres. It is highly suitable for facilities in Kampala, where compact, high-performance cooling is essential.

3. **Low-GWP Refrigerants**

Low-GWP refrigerants reduce greenhouse gas emissions by up to **90 per cent**, aligning with international environmental standards. They are suitable for all data centres as a straightforward substitution to improve sustainability.

4. **Centralized Cooling Units**

Centralized cooling improves efficiency by **5–10 per cent** for large facilities, making them a practical choice for industrial hubs. They are well-suited for large-scale or industrial data centres in urban areas like Kampala.

5. **Geothermal Cooling**

Geothermal cooling reduces energy use by **50 per cent** and ensures stable performance in regions with suitable underground temperatures. It is effective for urban areas like Kampala but requires significant initial investment.

6. **Free Chilling**

Free chilling saves up to **70 per cent energy** by using natural water sources for cooling. It is best suited for data centres near cold water sources like Lake Victoria.

7. **Free Cooling**

Free cooling reduces energy use by up to **30 per cent** by leveraging cooler outdoor air. It is most applicable in cooler regions such as Uganda's Western Highlands but has limited applicability in warmer, urban climates.

8. **Direct Expansion (DX) Cooling**

DX cooling offers precise cooling for smaller facilities but provides moderate energy savings compared to other advanced systems. It is best for modular or small-scale data centres.

4.3.4.2 Electrical Systems (CFO)

1. **High-Efficiency Inverters**

High-efficiency inverters achieve up to **98 per cent conversion efficiency**, reducing energy losses by 20–30 per cent compared to older systems. They are crucial for areas like Kampala and Entebbe, where variable grid quality can disrupt operations.

2. **Energy Storage Batteries**

Energy storage batteries provide sustainable backup power, reducing reliance on diesel generators and enabling renewable energy integration. They are particularly effective in rural areas with solar installations or regions with frequent grid outages.

3. **Microgrids and Cogeneration**

Microgrids integrate multiple energy sources, such as solar and hydro, enabling localized, independent energy generation. Cogeneration systems improve fuel efficiency by up to **70 per cent**, making them ideal for off-grid or rural areas like Karamoja.

4. **HVO Generators**

HVO generators reduce CO_2 emissions by up to **90 per cent**, offering a low-carbon alternative to diesel. They are suitable for urban areas like Kampala, where reducing air pollution is a priority.

4.3.4.3 Fire Suppression Systems

1. **Advanced Fire Detection Systems**

   Advanced systems provide early intervention, minimizing fire damage and ensuring operational continuity. They are essential for large facilities, particularly in remote regions where firefighting resources are limited.

2. **Water Mist Systems**

   Water mist systems consume 80–90 per cent less water than traditional sprinklers, protecting sensitive IT equipment with minimal resource use. They are suitable for urban centres like Kampala, where water availability supports efficient operation.

3. **Inert Gas Suppression Systems**

Inert gas systems provide residue-free, waterless suppression, ideal for sensitive IT environments. They are best for water-scarce regions like Karamoja or facilities prioritizing residue-free suppression.

4. **Clean Agent Suppression Systems**

Clean agent systems offer rapid suppression with low environmental impact, ideal for high-density IT facilities. They are suitable for environmentally conscious data centres in urban hubs like Kampala.

4.4 IT Room

The IT room is the operational hub of a data centre, housing the servers, storage devices, and networking infrastructure essential for processing and managing data. Optimizing its design and operation is crucial for energy efficiency, reduced cooling requirements, and sustainability. This section outlines key elements, their functions, and their energy-saving potential, alongside the importance of addressing local challenges specific to Uganda.

4.4.1 Airflow Optimization

Effective airflow management ensures that cooling systems deliver cold air precisely where needed while preventing inefficiencies caused by the mixing of hot and cold air.

4.4.1.1 Hot and Cold Aisle Configuration

Servers are arranged in alternating rows such that cold air intakes face one aisle (cold aisle) and hot air exhausts face the adjacent aisle (hot aisle). The separation of airflow minimizes recirculation of hot air and enhances cooling system performance.

- **Energy Benefits:** Reduces cooling system energy demand by 10–20 per cent, leading to substantial operational savings.
- **Application in Uganda:** An effective retrofitting option for existing facilities in Kampala or Entebbe to improve cooling without major structural changes.

Figure 35: IT Room Containment

4.4.1.2 Containment Systems

Physical barriers, such as plastic curtains or rigid panels, are used to isolate hot and cold airflows. This prevents air mixing, ensuring that cooled air reaches IT equipment more effectively.

- **Energy Benefits:** Reduces cooling energy needs by up to 30 per cent, significantly lowering the overall energy footprint of the data centre.
- **Application in Uganda:** Highly effective for high-density data centres in urban areas managing significant computational workloads.

4.4.2 IT Equipment

The selection and configuration of IT equipment play a pivotal role in reducing energy use, cooling requirements, and the overall environmental footprint of the data centre.

4.4.2.1 Energy-Efficient Servers

Modern servers incorporate features like automatic sleep modes and optimized power supplies to minimize energy use.

- **Energy Benefits:** Can lower energy consumption by **20–30 per cent** per server. For example, a data centre with 5,000 energy-efficient servers could save **131,400 kWh annually**, along with reduced cooling costs.
- **Application in Uganda:** Essential for upgrading legacy systems in government or financial sector data centres experiencing growing demand.

4.4.2.2 High-Density Storage Solutions (SSDs)

SSDs consume less power and generate less heat compared to traditional HDDs, reducing energy requirements for storage and associated cooling systems.

- **Energy Benefits:** Reduces storage energy consumption by up to **50 per cent**, while requiring less physical space.
- **Application in Uganda:** Ideal for institutions managing large datasets, such as healthcare and telecom providers, where efficiency and reliability are paramount.

4.4.2.3 Virtualization and Workload Consolidation

Virtualization technology allows multiple workloads to run on fewer physical servers, optimizing resource use and minimizing energy consumption.

- **Energy Benefits:** Consolidating workloads through virtualization can halve the number of servers required, saving up to **438,000 kWh annually** in a facility consuming 876,000 kWh.
- **Application in Uganda:** Adoption is currently limited as most data centre clients prefer co-location services and provide their own servers, hindering the development of virtualization and efficient workload management. This preference increases energy use and environmental impact. Change management initiatives will be essential to help clients understand the benefits of migrating from co-location to cloud hosting services, such as improved efficiency, lower operational costs, and reduced emissions.

4.4.3 Workload Management

Efficient workload managemen ensures that IT resources are dynamically allocated based on real-time demand, minimizing waste and maximizing system efficiency.

4.4.3.1 Orchestration Tools:

These tools enable automatic scaling of IT resources based on demand. During periods of low activity, unnecessary servers can be powered down or put into idle mode, conserving energy.

- **Energy Benefits:** Enhances energy efficiency by **10–20 per cent**, saving approximately **175,200 kWh annually** for a 1 MW data centre.
- **Application in Uganda:** Ideal for cloud-based services or institutions managing variable workloads, such as e-governance or academic platforms. Adoption will require client education to transition from physical server co-location to efficient cloud services.

4.4.3.2 Data Management Techniques

- **Tiering:** Frequently accessed data is stored on high-speed SSDs, while less critical data is moved to low-power storage systems.
- **Compression:** By reducing the size of stored data, compression decreases the energy required for storage and retrieval operations.
- **Energy Benefits:** Combined, these strategies can reduce storage energy use by up to **30 per cent.**
- **Application in Uganda:** Particularly beneficial for data centres serving the telecommunications and financial sectors, where data volumes are growing rapidly.

4.4.4 Recommended Prioritization for IT Room

1. **Airflow Optimization:** Implement hot and cold aisle configurations and containment systems to enhance cooling efficiency and reduce energy consumption.
2. **IT Equipment:** Upgrade to energy-efficient servers and SSD storage solutions to lower power consumption and cooling requirements. Adopt virtualization to consolidate workloads and reduce hardware needs. Launch change management initiatives to encourage clients to shift from co-location to cloud hosting for greater efficiency and reduced emissions.
3. **Workload Management:** Use orchestration tools and intelligent data management strategies to optimize resource utilization and minimize energy waste.

By focusing on these strategies, Uganda's data centres can significantly enhance energy efficiency, reduce operational costs, and support the sustainable growth of digital infrastructure. This approach aligns with increasing demand for data services while addressing the challenges of transitioning from co-location to more efficient hosting models.

5 Eco-Construction Standards

Eco-construction aims to minimize the environmental impact of data centre development, focusing on sustainability during the construction phase. By leveraging responsible building practices, efficient use of resources, and rehabilitating existing infrastructure, eco-construction supports Uganda's digital transformation while preserving environmental integrity. This chapter outlines tailored strategies for Uganda to optimize resource use and minimize emissions.

5.1 Site Preparation and Minimizing Land Impact

Proper site preparation is essential to reduce environmental disturbance while setting the foundation for sustainable construction.

5.1.1 Environmental Impact Assessments (EIA)

Conduct EIAs to identify ecologically sensitive areas, ensuring minimal disruption to habitats and local biodiversity. Incorporate green buffers or wildlife corridors to mitigate impacts.

- **Application in Uganda:** Sites near Lake Victoria or areas with high biodiversity value should integrate protective measures.

5.1.2 Soil and Erosion Management

Techniques such as retaining walls, vegetation planting, and silt fences prevent soil erosion and sedimentation of nearby water bodies.

- **Application in Uganda:** Critical in sloped regions like the Western Highlands to protect farmland and ecosystems.

5.2 Low-Impact Construction Techniques

Adopting sustainable construction techniques reduces environmental and social disruption while optimizing efficiency.

5.2.1 Modular and Prefabricated Construction

Off-site prefabrication minimizes on-site waste, shortens construction timelines, and reduces local environmental impact.

- **Application in Uganda:** Prefabricated modules are ideal for semi-urban and remote areas where on-site construction logistics are challenging.

Figure 36: Prefabricated data centre

5.2.2 Sustainable Transportation Logistics

Use digital logistics systems to optimize transportation routes and minimize emissions. Source materials locally to reduce transport distances. It will reduce emissions by up to **15 per cent** and lowers costs.

- **Application in Uganda:** Prioritize local suppliers in Kampala and other urban hubs.

5.2.3 Recycling and Reuse:

Implement on-site recycling of construction waste, such as concrete, steel, and wood. Divert usable materials to other construction projects.

- **Application in Uganda:** Supports circular economy goals, particularly in Kampala where recycling networks exist.

5.3 Water and Energy Conservation During Construction

Efficient water and energy use during the construction phase can significantly reduce resource waste.

5.3.1 Rainwater Harvesting

Install temporary rainwater collection systems for non-potable uses such as cleaning and concrete mixing.

- **Application in Uganda:** Essential in water-scarce areas like Karamoja.

5.3.2 Renewable Energy Solutions

Use portable solar panels or battery storage systems to power construction sites, reducing reliance on diesel generators.

- **Application in Uganda:** Effective in regions with inconsistent grid supply, such as rural districts.

5.4 Rehabilitation of Existing Structures

Rehabilitating underutilized or abandoned buildings provides a sustainable alternative to new construction. This approach reduces material use, limits waste, and minimizes land disturbance while modernizing existing infrastructure.

5.4.1 Structural Assessments:

Conduct detailed assessments of existing buildings to evaluate their potential for conversion into data centres. Focus on structural integrity, cooling system compatibility, and energy efficiency improvements.

- **Application in Uganda:** Urban centres like Kampala have a range of underutilized industrial buildings that can be retrofitted for data centre use.

5.4.2 Environmental and Financial Benefits:

- **Carbon Footprint Reduction:** Retrofitting reduces emissions by avoiding the production and transport of new materials.
- **Cost Savings:** Rehabilitation can lower construction costs by up to **30 per cent** compared to new builds.
- **Example:** Retrofitting a 1,000 m^2 facility in Kampala could save an estimated **120 metric tons of CO_2 emissions.**

5.4.3 Modernization for Compliance

Upgrades ensure that rehabilitated buildings meet international standards for data centre performance.

- **Examples**:
  - Installation of advanced cooling systems like hot and cold aisle configurations.
  - Integration of high-efficiency power distribution systems.
- **Application in Uganda:** Enables cost-effective modernization for industries like finance and telecommunications.

5.4.4 Optimized Resource Use:

Reusing existing structures reduces demand for new construction materials by **40 per cent**, conserving natural resources.

- **Application in Uganda:** Reduces urban sprawl and revitalizes underutilized areas, promoting sustainable urban planning.

5.5 Post-Construction Restoration

Post-construction efforts ensure that sites are rehabilitated to support long-term environmental sustainability.

5.5.1 Reforestation and Landscaping

Incorporate native vegetation to restore habitats and manage stormwater runoff. Use permeable pavements to prevent flooding.

- **Application in Uganda:** Helps combat urban heat islands in Kampala and other rapidly growing cities.

5.5.2 Community Integration:

Collaborate with local communities to plant trees, create green spaces, or develop shared facilities.

- **Benefits:** Enhances community relationships and promotes local ownership.
- **Application in Uganda:** Particularly effective in peri-urban areas where communities may rely on surrounding ecosystems.

5.6 Recommended Prioritization for Eco-Construction Standards

1. **Site Preparation and Environmental Impact Mitigation:** Conduct comprehensive Environmental Impact Assessments (EIAs) to identify ecologically sensitive areas and integrate protective measures such as green buffers and wildlife corridors. These steps are essential to minimize land disturbance and biodiversity loss during construction, particularly in regions like Lake Victoria or the Western Highlands.
2. **Modular and Prefabricated Construction:** Adopt modular designs and off-site prefabrication to reduce on-site waste, shorten construction timelines, and minimize local environmental impact. This approach is particularly effective in semi-urban and remote areas of Uganda, where logistics can be challenging.
3. **Water Management Systems:** Install temporary rainwater harvesting systems to supply water for non-potable uses during the construction phase, particularly in water-scarce areas such as Karamoja. This reduces reliance on municipal water resources while supporting sustainable construction practices.
4. **Sustainable Transportation Logistics:** Prioritize sourcing materials locally and using digital logistics systems to optimize transportation routes. This minimizes emissions and supports Uganda's local suppliers, particularly in urban hubs like Kampala.
5. **Recycling and Reuse of Materials:** Implement on-site recycling programs to manage construction waste efficiently. Materials such as concrete, steel, and wood should be diverted for reuse in other projects, aligning with Uganda's circular economy goals.
6. **Rehabilitation of Existing Structures:** Conduct structural assessments of underutilized buildings in urban centres such as Kampala to evaluate their potential for retrofitting into data centres. This reduces the need for new construction, lowering carbon footprints and revitalizing urban spaces.
7. **Energy Conservation During Construction:** Utilize portable solar panels and battery storage systems to power construction sites in rural and semi-urban areas. This reduces reliance on diesel generators and aligns with Uganda's renewable energy goals.

8. **Post-Construction Restoration:** Incorporate native vegetation into landscaping plans to restore habitats and manage stormwater runoff. Use permeable pavements to prevent flooding and reduce heat retention in urban areas. These measures are particularly relevant in fast-growing cities like Kampala.
9. **Community Engagement:** Collaborate with local communities to create green spaces, plant trees, and develop shared facilities. These efforts build community ownership and foster positive relationships, particularly in peri-urban areas.

6 Operation and Maintenance Standards

Operation and maintenance standards for data centres are critical for ensuring efficiency, sustainability, and long-term resilience. These standards encompass energy monitoring, predictive maintenance, optimized cooling, and effective resource management. For Uganda, where energy reliability and resource efficiency are paramount, these practices are essential for creating sustainable digital infrastructure.

6.1 Energy Monitoring and Optimization

6.1.1 Real-Time Energy Monitoring

Implementing real-time energy monitoring systems allows data centres to continuously track energy consumption and operational efficiency. Key metrics such as Power Usage Effectiveness (PUE) and Energy Reuse Factor (ERF) provide insights into energy utilization, enabling operators to pinpoint inefficiencies and take immediate corrective actions.

- **Benefits:** Real-time monitoring can reduce energy consumption by up to 20 per cent through informed decision-making and immediate corrective actions.
- **Application in Uganda:** Urban data centres in Kampala and Entebbe, where grid fluctuations are common, benefit from energy monitoring to ensure uninterrupted operations and optimize costs.

6.1.2 Dynamic Energy Management

By aligning energy use with IT workload demand, data centres avoid overconsumption during periods of low activity. Intelligent energy distribution minimizes peaks and ensures systems operate within optimal efficiency ranges.

- **Impact:** Dynamic energy management can achieve energy savings of 10–15 per cent

6.2 Predictive Maintenance

Predictive maintenance leverages advanced tools such as IoT sensors and AI to anticipate equipment failures, optimize maintenance schedules, and enhance system reliability.

- **Key Techniques**:
  - Sensors monitor temperature, vibration, and performance in real time.
  - AI algorithms predict failures, enabling timely interventions.
- **Benefits:** Extends equipment lifespan, reduces downtime by up to 30 per cent, and lowers maintenance costs.
- **Application in Uganda:** Particularly useful for rural or remote data centres, where immediate access to replacement parts or technical expertise is limited.

6.3 Cooling System Optimization

Cooling systems are among the most energy-intensive components of a data centre, often accounting for 30–40 per cent of total energy use. Optimizing these systems presents a significant opportunity for improving overall efficiency and sustainability.

6.3.1 Efficient Cooling Solutions

Modern cooling technologies such as evaporative cooling and liquid-based cooling deliver superior thermal management while reducing energy consumption.

- **Evaporative Cooling:** Uses water evaporation to cool incoming air, significantly reducing reliance on mechanical chillers.
- **Liquid-Based Cooling:** Directly cools IT equipment, such as CPUs and GPUs, by circulating coolant, which is highly effective for high-density data centres.

6.3.2 Airflow Management

Effective airflow management ensures that cooling is targeted where it is most needed, avoiding inefficiencies caused by the mixing of hot and cold air.

- **Hot and Cold Aisle Configurations:** Servers are arranged to segregate hot and cold airflows, enhancing cooling system efficiency by up to 30 per cent.
- **Containment Systems:** Physical barriers such as curtains or rigid panels isolate airflows, ensuring optimal cooling and minimizing energy waste.

6.3.3 Temperature Adjustments

Raising the operating temperature by 2°C can reduce cooling energy consumption by 5–10 per cent.

- **Application in Uganda:** High-density data centres in Kampala require robust cooling solutions tailored to local climate conditions. Techniques such as night cooling are particularly relevant in cooler regions like the Western Highlands.

6.4 Resource Management and Waste Reduction

6.4.1 Water Conservation

Efficient water management is critical for sustainable data centre operations, particularly in regions facing water scarcity. Integrating rainwater harvesting and closed-loop cooling systems minimizes the environmental footprint of water use.

6.4.1.1 Rainwater Harvesting

Rainwater collection systems can be installed to supply water for non-potable applications such as cooling tower makeup, cleaning, and landscaping. By reducing dependence on municipal water supplies, these systems offer a sustainable solution.

- **Impact:** Rainwater harvesting can reduce municipal water consumption by up to 30 per cent. This is particularly valuable in regions like Karamoja, where water resources are limited.

- **Application in Uganda:** Rural data centres in water-scarce areas can benefit significantly from this approach, supporting broader efforts to ensure sustainable water use.

6.4.1.2 Closed-Loop Cooling Systems

These systems recycle water within a sealed loop, drastically reducing the amount of fresh water needed for cooling processes.

- **Advantages:** Such systems also lower wastewater discharge, minimizing environmental impacts.

6.4.2 Waste Management and Recycling

Effective waste management practices play a central role in reducing the ecological footprint of data centres. These strategies focus on both electronic and non-electronic waste streams to ensure sustainable disposal and reuse.

6.4.2.1 Electronic Waste Recycling

- **Valuable Material Recovery:** Recycling outdated servers, batteries, and networking equipment allows for the extraction of valuable metals and components, reducing the need for new material production.
- **Refurbishment Programs:** Functional components from decommissioned equipment can be refurbished and redeployed, extending their lifecycle and reducing procurement costs.
- **Application in Uganda:** Establishing partnerships with recycling companies in urban hubs like Kampala supports the development of a circular economy while addressing electronic waste challenges.

6.4.2.2 Non-Electronic Waste Recycling

- **Recycling Initiatives:** Sorting and recycling construction debris, packaging, plastics, and metals prevents landfill accumulation.
- **Minimizing Procurement Waste:** Data centres can limit packaging waste by sourcing equipment from vendors that use sustainable packaging solutions.
- **Local Valorization:** Unused materials, such as pallets and crates, can be repurposed for local community projects or donated to other industries.
- **Impact:** Comprehensive recycling programs reduce landfill waste, recover valuable materials, and foster sustainable community partnerships.

6.5 Workforce Training and Standards Compliance

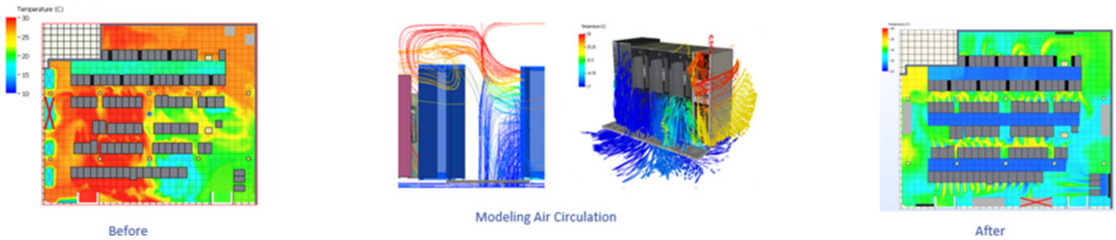
6.5.1 Continuous Training

The operational success of data centres relies on a skilled workforce capable of implementing advanced technologies and sustainable practices. Training programs should focus on equipping staff with the knowledge to enhance efficiency and maintain compliance with international standards.

- **Key Training Areas**:
    - **Energy Metrics:** Training on indicators such as Power Usage Effectiveness (PUE) and Energy Reuse Factor (ERF) enables teams to track and optimize energy efficiency.

  - o **Technology Proficiency:** Teams should be trained to use predictive maintenance tools, AI-driven energy optimization systems, and CFD (Computational Fluid Dynamics) simulations to design efficient cooling layouts and troubleshoot inefficiencies.
  - o **Sustainability Practices:** Staff must understand recycling protocols, water conservation methods, and waste management strategies to align with global best practices.
- **Impact:** A trained workforce can reduce operational inefficiencies, lower energy costs, and ensure adherence to sustainability goals.

Figure 37: Airflow Simulation for Optimized Cooling Efficiency



6.5.2 Standards Compliance

Ensuring alignment with global standards fosters transparency, operational excellence, and environmental stewardship in data centre operations.

6.5.2.1 Compliance Audits

- o Regular audits identify areas for improvement in energy efficiency, cooling system performance, and waste management.
- o These assessments support the development of targeted action plans to address inefficiencies and enhance resilience.

6.5.2.2 Adherence to International Standards

- o ISO 50001 (Energy Management): Guides the establishment of robust energy practices to minimize consumption and costs.
- o ISO 14001 (Environmental Management): Promotes practices that reduce the environmental impact of data centre operations.
- o **Application in Uganda:** Compliance with these standards demonstrates a commitment to sustainable growth, appealing to local stakeholders and international partners.

6.6 Recommended Prioritization for Operation and Maintenance Standards

1. **Energy Monitoring and Optimization**: Implement real-time monitoring systems to continuously track energy usage, leveraging metrics such as Power Usage Effectiveness (PUE) and Energy Reuse Factor (ERF) for actionable insights. Dynamic energy management should be integrated to align power consumption with IT workload demands, ensuring systems operate within optimal efficiency ranges. These strategies can reduce energy consumption by 15–20 per cent, significantly cutting operational costs in urban centres like Kampala and Entebbe.
2. **Cooling System Optimization**: Focus on efficient cooling technologies such as liquid-based and evaporative cooling, complemented by robust airflow management systems like hot and cold aisle configurations. Adjust operating temperatures to achieve a balance between thermal stability and energy savings, reducing cooling energy use by 5–30

per cent. In cooler regions, explore opportunities for free cooling to further enhance sustainability.

3. **Predictive Maintenance**: Deploy IoT sensors and AI-driven tools to anticipate equipment failures and optimize maintenance schedules. By addressing potential issues proactively, data centres can reduce downtime by up to 30 per cent and extend the lifespan of critical infrastructure. This is particularly vital for remote or rural centres where access to replacement parts or technical expertise is limited.
4. **Resource Management and Waste Reduction**: Integrate rainwater harvesting and closed-loop cooling systems to minimize water consumption. Establish robust recycling programs for electronic and non-electronic waste to recover valuable materials and reduce landfill dependency. Partnerships with local recycling firms in urban hubs can strengthen the circular economy while promoting sustainability.
5. **Workforce Training and Standards Compliance**: Implement continuous training programs to equip staff with the skills needed for energy monitoring, predictive maintenance, and advanced cooling techniques. Regular compliance audits should align operations with international standards such as ISO 50001 and ISO 14001, ensuring both environmental stewardship and operational excellence.

By prioritizing these strategies, Uganda's data centres can enhance energy efficiency, minimize resource use, and align with international sustainability goals. This approach supports the country's digital transformation while ensuring resilience and environmental integrity.

7 Summary of Guidelines

7.1 P1 (High Priority)

Actions offering the most immediate and significant benefits in sustainability, energy efficiency, scalability, and cost-effectiveness.

7.1.1 Certifications (New and Existing Sites)

- **ISO 14001: Environmental Management Systems**

ISO 14001 is a globally recognized framework that helps organizations identify, manage, and reduce their environmental impacts. For data centres, this certification ensures a systematic approach to minimizing resource waste, optimizing energy use, and adhering to environmental regulations. The certification process involves regular audits and the establishment of sustainability goals, ensuring continuous improvement. In Uganda, ISO 14001 is particularly critical for attracting international investment and ensuring sustainable growth in the ICT sector while addressing pressing environmental challenges.

- **ITU/World Bank Guide for Green Data Centres**

The ITU/World Bank Guide is a comprehensive resource designed to support the development of sustainable data centres in resource-constrained regions. It offers practical strategies for integrating renewable energy, deploying efficient cooling technologies, and adopting modular designs to enhance scalability. Tailored for developing countries, the guide emphasizes cost-effective solutions and operational resilience, making it a perfect fit for Uganda's infrastructure and climate challenges.

- **PUE (Power Usage Effectiveness)**

PUE is a metric that evaluates a data centre's energy efficiency by comparing total energy consumption with energy used solely for IT equipment. A lower PUE indicates greater efficiency. This metric helps operators pinpoint inefficiencies, particularly in non-IT operations like cooling and lighting, and implement targeted improvements. In Uganda, where energy costs are high, optimizing PUE can lead to significant operational savings and reduce the environmental impact of data centre operations.

7.1.2 Optimal Sizing (New Sites)

- **Adopt Modular Systems**

Modular systems involve constructing data centres in scalable units, allowing for phased development as demand grows. This approach minimizes upfront costs, reduces waste during construction, and provides flexibility to adapt to future needs. Modular systems are especially valuable in Uganda, where ICT infrastructure is still developing, and demand is expected to grow rapidly. By adopting this approach, Uganda can ensure efficient resource allocation and avoid overbuilding while supporting gradual expansion aligned with market requirements.

- **Focus on Energy-Efficient Solutions**

Energy-efficient technologies, such as high-performance cooling systems, advanced lighting, and efficient power distribution units, reduce energy consumption without compromising operational performance. These solutions directly address Uganda's high electricity costs and grid stability issues, providing reliable operations while lowering greenhouse gas emissions. Implementing energy-efficient systems supports the country's transition to sustainable infrastructure and enhances operational resilience in both urban and rural data centres.

7.1.3 Sustainable Building Design (New Sites)

This section focuses on foundational design principles to optimize resource use, ensure energy efficiency, and minimize environmental impacts over the lifecycle of data centres.

- **Connectivity and Logistical Access**

Strategic placement of data centres near essential infrastructure—such as fiber-optic networks, transportation hubs, and skilled labor pools—ensures operational efficiency and reduces emissions during construction and maintenance. For instance, data centres in Kampala can leverage the city's existing telecommunications and transport infrastructure to streamline operations. Reducing transport-related emissions also contributes to lowering the carbon footprint of logistics. In Uganda, this approach aligns with the dual goals of minimizing operational costs and supporting urban growth.

- **Renewable Energy Proximity**

Locating data centres near renewable energy sources, such as hydroelectric plants or solar farms, reduces dependency on fossil fuels and lowers operational emissions. Uganda's renewable energy resources are abundant, with over 90 per cent of the national electricity supply coming from renewables like hydroelectricity. By positioning facilities close to these sources, data centres can eliminate energy transmission losses and stabilize their power supply. This strategy also supports Uganda's commitment to expanding its renewable energy capacity under its Vision 2040 plan.

7.1.4 Cooling Systems (New and Existing Sites)

Cooling is one of the most energy-intensive operations in data centres, making advanced cooling systems a priority for achieving sustainability and efficiency.

- **Adiabatic Cooling**

Adiabatic cooling leverages the evaporation of water to cool incoming air, reducing the reliance on energy-intensive mechanical cooling systems. This method is especially effective in Uganda's drier regions, where low humidity enhances its efficiency. By adopting adiabatic cooling, data centres can cut cooling energy consumption by up to 90 per cent, providing significant cost savings while minimizing environmental impact. For example, a medium-sized data centre using adiabatic cooling could save hundreds of thousands of kilowatt-hours annually, translating into substantial financial and energy gains.

- **Direct Liquid Cooling (DLC)**

DLC delivers liquid coolants directly to heat-generating IT components, such as CPUs and GPUs, efficiently removing heat at its source. This system bypasses the inefficiencies of air-based cooling and enables higher server density, which is ideal for urban centres like Kampala. DLC systems also allow for precise temperature control, ensuring optimal performance and extended equipment lifespan. For Uganda's growing ICT sector, DLC offers a scalable solution that balances performance and sustainability.

- **Low-GWP Refrigerants**

Refrigerants with low Global Warming Potential (GWP), such as HFOs (Hydrofluoroolefins), significantly reduce the greenhouse gas emissions associated with cooling systems. These refrigerants maintain high energy efficiency while aligning with international climate standards, such as the Kigali Amendment to the Montreal Protocol. For Ugandan data centres, transitioning to low-GWP refrigerants future-proofs cooling operations against regulatory changes and enhances their environmental credentials.

7.1.5 Electrical Systems (New and Existing Sites)

Efficient electrical systems are critical for reducing energy losses, stabilizing power supply, and integrating renewable energy sources in data centres.

- **High-Efficiency Inverters**

Inverters are essential for converting electricity into usable forms for IT equipment, and high-efficiency models minimize energy loss during this process. With conversion efficiencies of up to 98 per cent, these inverters ensure minimal wastage of power, which is especially valuable in Uganda, where energy costs are high and grid stability can be inconsistent. Implementing high-efficiency inverters not only reduces operational costs but also supports continuous operations during grid fluctuations. For example, a data centre using high-efficiency inverters can save tens of thousands of kilowatt-hours annually, directly lowering electricity bills and emissions.

- **Energy Storage Batteries**

Advanced battery systems store excess power from renewable sources and provide reliable backup during outages. These batteries are crucial in Uganda, where power interruptions are common. By integrating storage systems with solar or hydroelectric energy, data centres can ensure uninterrupted operations while reducing reliance on diesel generators. Lithium-ion batteries, in particular, are well-suited for Ugandan data centres due to their long lifespan, scalability, and efficiency in energy retention.

7.1.6 IT Room (New and Existing Sites)

Efficient IT room design enhances the performance of data centres while minimizing energy use and operational costs.

- **Airflow Optimization**

Implementing hot and cold aisle containment in IT rooms ensures that cool air is directed to equipment intake and prevents the mixing of hot and cold air streams. This optimization reduces the workload on cooling systems, lowering energy consumption and extending the lifespan of IT hardware. For example, a properly optimized airflow system can reduce cooling energy use by 15–20 per cent, making it a practical and impactful solution for data centres in Uganda's warmer regions.

- **IT Equipment**

Upgrading to energy-efficient IT hardware, such as servers with advanced power management features and SSD storage, reduces power consumption and heat output. Virtualization technologies further optimize resource utilization by consolidating workloads, reducing the need for physical servers. In Uganda, where the ICT sector is expanding, deploying energy-efficient IT equipment supports sustainable growth while cutting operational costs.

7.1.7 Fire Protection Systems (Existing Sites)

- **Advanced Fire Detection Systems**

Early-warning systems capable of identifying fire risks at their inception, reducing potential damage and ensuring rapid intervention. These systems are vital for large data centres where immediate response times are critical to avoid catastrophic losses.

- **Water Mist Systems**

Fine mist suppression minimizes water usage and is designed to avoid damaging sensitive IT equipment. Effective for high-density facilities in Uganda, particularly where water resources are moderately available.

7.1.8 Operation and Maintenance (Existing Sites)

Proactive operation and maintenance strategies ensure that data centres operate at peak efficiency and avoid unnecessary resource wastage.

- **Energy Monitoring and Optimization**

Real-time monitoring systems track energy consumption across the facility, enabling operators to identify inefficiencies and implement corrective measures promptly. Dynamic energy management tools, such as those using AI-driven analytics, can automatically adjust power usage based on workload demand. In Uganda, where energy prices are high, these systems are crucial for managing costs and ensuring efficient resource use.

- **Cooling System Optimization**

Routine maintenance and optimization of cooling systems, including cleaning filters, recalibrating sensors, and adjusting temperature set points, ensure they operate efficiently. For example, recalibrating cooling systems in an existing data centre can reduce energy use by 5–30 per cent, depending on the baseline efficiency of the system. In Uganda's high-temperature regions, cooling optimization is essential for maintaining reliability and sustainability.

7.2 P2 (Medium Priority)

These actions are important for scalability and sustainability but may require more resources, longer implementation timelines, or strategic alignment to achieve full impact.

7.2.1 Certifications (New and Existing Sites)

- **ASHRAE Guidelines:** A set of recommendations for designing and maintaining HVAC systems to optimize energy efficiency. While not a formal certification, these guidelines are critical for cooling system efficiency, particularly in Uganda's hot climate.
- **LEED (Leadership in Energy and Environmental Design):** A globally recognized green building certification that enhances sustainability credibility. Achieving LEED certification demonstrates environmental stewardship but requires significant financial and administrative resources.
- **EU Code of Conduct (CoC):** Offers practical, adaptable guidelines for energy-efficient data centre operations. While developed for European facilities, its principles can be adapted for Uganda's context.

7.2.2 Optimal Sizing

Data-driven projections involve analyzing ICT adoption trends, digital demand forecasts, and population growth to size infrastructure appropriately. This ensures that data centres are neither underbuilt nor overbuilt, avoiding wasted resources while meeting future needs. For Uganda, where digital infrastructure is expanding rapidly, these projections enable strategic planning and prevent inefficient investments. For example, integrating real-time data analytics into planning can help operators anticipate workload growth and allocate resources effectively.

7.2.3 Sustainable Building Design (New Sites)

- **Favorable Climate Integration**

By strategically selecting cooler regions or implementing free cooling techniques that leverage natural temperature differentials, data centres can reduce their reliance on mechanical cooling systems. For example, Uganda's Western Highlands offer opportunities to utilize ambient air cooling, reducing energy use for HVAC systems. Additionally, integrating shading structures or reflective materials in building design minimizes heat absorption, further reducing cooling loads.

- **Resilience to Climate Risks**

Data centres in Uganda must be designed to withstand climate-related challenges such as floods, extreme heat, and storms. Resilient designs incorporate elevated structures to mitigate flood risks, reinforced building materials to endure heavy rainfall, and backup power systems to handle outages during extreme weather. For example, facilities in flood-prone areas near Lake Victoria can use elevated platforms and water-resistant materials to ensure long-term operational reliability.

7.2.4 Cooling Systems (New and Existing Sites)

- **Centralized Cooling Units**

Centralized cooling systems improve energy efficiency in larger facilities by consolidating cooling operations and streamlining temperature control. These systems can provide consistent cooling to multiple server halls, making them ideal for industrial-scale data centres in Uganda. Although upfront costs are higher, centralized systems reduce long-term operational expenses by optimizing energy distribution.

- **Free Chilling**

Free chilling utilizes natural cold water sources, such as Lake Victoria, to cool data centre systems without relying on energy-intensive compressors. This approach is particularly viable for data centres near natural bodies of water. By harnessing existing resources, operators can achieve substantial energy savings while maintaining sustainable operations.

- **Free Cooling**

Free cooling involves using cooler outdoor air to manage heat loads, reducing the energy required for mechanical cooling. This technique is most applicable in Uganda's cooler regions, such as the Rwenzori Mountains, where ambient temperatures can naturally lower facility heat levels. Operators can also integrate economizers into HVAC systems to maximize efficiency when outdoor conditions are favorable.

7.2.5 Fire Protection Systems (Existing Sites)

- **Inert Gas Suppression Systems**

  Employ inert gases (e.g., argon or nitrogen) to suppress fires in sensitive areas. Effective for mission-critical facilities but costly to install and maintain, making them more suitable for advanced setups.

7.2.6 Eco-Construction Standards (New Sites)

- **Recycling and Reuse of Materials**

During construction, materials like concrete, steel, and wood can be recycled and reused, reducing the environmental impact of new data centre builds. This aligns with Uganda's goals for promoting a circular economy and minimizing construction waste. For example, reclaimed steel can be repurposed for structural elements, while recycled concrete can be used in sub-base layers for building foundations.

- **Rehabilitation of Existing Structures**

Instead of constructing entirely new facilities, underutilized buildings in urban centres like Kampala can be retrofitted to serve as data centres. Retrofitting reduces embodied carbon emissions by avoiding the need for new materials and construction processes. It also revitalizes unused infrastructure, promoting sustainable urban development.

7.2.7 Operation and Maintenance (Existing Sites)

- **Predictive Maintenance**

Predictive maintenance uses IoT sensors and AI analytics to monitor equipment health and predict failures before they occur. This reduces downtime, extends equipment lifespan, and prevents resource wastage. For Uganda, predictive maintenance ensures that data centres can operate reliably in areas where access to spare parts or technical expertise may be limited.

- **Resource Management and Waste Reduction**

Rainwater harvesting systems and closed-loop water cooling processes minimize water use in data centre operations. Additionally, recycling programs for electronic and non-electronic waste reduce dependency on landfills while recovering valuable materials. These measures align with Uganda's sustainability goals and support the development of a circular economy.

7.3 P3 (Low Priority)

These actions are resource-intensive, highly specialized, or provide limited short-term benefits. They are more suited advanced stages of infrastructure maturity or specific scenarios.

7.3.1 Cooling Systems (New and Existing Sites)

- **Geothermal Cooling**

Geothermal cooling uses underground heat exchangers to leverage stable subsurface temperatures for efficient cooling. This method significantly reduces reliance on traditional mechanical cooling systems and offers long-term energy savings. However, geothermal systems require extensive geological surveys, high initial investments, and specific environmental conditions. In Uganda, regions with favorable underground temperatures could implement this system, but it may only be viable for larger, long-term projects.

Example: A large-scale data centre in Kampala could achieve stable cooling operations while reducing overall energy use by up to 50 per cent.

- **Direct Expansion (DX) Cooling**

DX cooling uses refrigerants to cool air in smaller, self-contained systems, making it suitable for modular or small-scale data centres. While the energy savings are moderate (5–10 per cent), the simplicity and cost-effectiveness of DX cooling make it an attractive option for sites with limited budgets or lower-density setups. This is particularly relevant for smaller facilities in Uganda's peri-urban areas.

7.3.2 Eco-Construction Standards (New Sites)

- **Energy Conservation During Construction**

Portable solar panels and battery systems can be used to power construction equipment, reducing reliance on diesel generators. While challenging to scale, this approach aligns with Uganda's renewable energy ambitions and minimizes emissions during the construction phase. It is particularly impactful for semi-urban and rural construction projects where grid access is limited.

- **Post-Construction Restoration**

Integrating native vegetation, permeable pavements, and green buffers into post-construction landscaping helps restore ecosystems and manage stormwater runoff. This strategy is valuable for fast-growing cities like Kampala, where urban heat islands and flooding are concerns. While these measures do not directly enhance operational performance, they improve environmental outcomes and align with sustainable development goals.

- **Community Engagement**

Engaging local communities through green initiatives, such as tree planting and shared green spaces, fosters goodwill and encourages local participation in sustainable projects. While these efforts do not directly impact data centre efficiency, they create a positive social impact, enhancing the project's reputation and supporting Uganda's broader environmental goals.

7.3.3 Operation and Maintenance (Existing Sites)

- **Energy Recycling**

Advanced systems that capture and repurpose waste heat from servers, such as heat pumps or district heating, offer innovative ways to improve energy efficiency. For example, waste heat can be used to warm nearby office spaces or greenhouses. While this approach is resource-intensive and requires additional infrastructure, it represents a forward-thinking strategy for large-scale facilities in urban areas.

8 Implementation Plan for Green Data Centre Standards

The implementation of green data centre standards in Uganda requires a structured, phased approach to enable operators, policy-makers, and investors to transition toward sustainable infrastructure. This plan aligns with Uganda's national priorities and international commitments, offering a clear roadmap for short-, medium-, and long-term actions.

8.1 Short-Term Goals (1 to 2 years)

Objective: Lay the foundation for ecological transformation by implementing monitoring tools, strengthening local capacity, and initiating pilot programs.

a. Key Actions:

- **Initial Assessment of Existing Data Centres**
  - Conduct environmental audits to evaluate current energy consumption, waste management, and carbon emissions.
  - Identify modernization opportunities, such as integrating energy-efficient cooling systems (e.g., adiabatic cooling) and intelligent energy management technologies.
- **Capacity Building**
  - Implement training programs for data centre managers and technicians on key standards, including **ISO 14001** and **ISO 50001**.
  - Partner with universities and technical institutes to integrate green data centre modules into curricula, fostering local expertise.
- **Deployment of Monitoring Tools**
  - Install real-time monitoring systems to track metrics such as Power Usage Effectiveness (PUE), water consumption, and CO_2 emissions.
  - Use data collected from these systems to establish baseline benchmarks for energy and environmental performance.
- **Strategic Partnerships**
  - Engage international organizations for technical and financial support in implementing green initiatives.
  - Foster collaborations with global technology providers to access advanced, sustainable solutions.

b. Expected Outcomes:

- A clear understanding of sustainability needs and improvement opportunities.
- A strong foundation for long-term investments in sustainability.

8.2 Medium-Term Goals (3 to 5 years)

Objective: Modernize infrastructure, promote certification adoption, and construct sustainable pilot data centres.

a. Key Actions:

- **Modernization of Existing Infrastructure**:
  - Retrofit cooling systems with advanced technologies like evaporative cooling or hot/cold aisle containment.
  - Replace outdated IT and power equipment with certified energy-efficient models, reducing operational emissions.
- **Construction of Pilot Data Centres**:
  - Design and build pilot facilities based on modular, scalable architectures powered by renewable energy sources such as solar or hydroelectricity.
  - Evaluate the performance of these pilot centres and share insights with stakeholders to encourage broader adoption.
- **Encouragement of Certifications**:
  - Support operators in achieving certifications like ISO 50001 for energy efficiency and LEED for sustainable design.
- **Enhanced Waste Management**:
  - Partner with local companies for electronic waste recycling and establish dedicated facilities for sorting and recovery.
- **Promote Virtualization and Cloud Adoption**
  - Develop initiatives to educate clients about the benefits of transitioning from co-location to cloud services and virtualization, such as enhanced scalability, reduced resource use, and cost savings.
  - Conduct targeted campaigns and workshops to demonstrate the environmental and operational advantages of adopting virtualized IT infrastructures.
  - Collaborate with stakeholders to build trust and address common concerns about security and performance in cloud-based services.

b. Expected Outcomes:

- Measurable reductions in energy consumption and carbon emissions across Uganda's data centres.
- Accelerated adoption of green standards and certifications by local operators.
- Development of a green innovation ecosystem supporting sustainable ICT infrastructure.
- Increased uptake of cloud and virtualization solutions, contributing to greater energy efficiency and sustainability.

8.3 Long-Term Goals (5 years and beyond)

Objective: Mainstream green data centre standards and position Uganda as a regional leader in sustainable digital infrastructure.

a. Key Actions:

- **National Expansion of Green Standards**:
  - o Introduce legislation requiring all new data centres to adhere to ecological benchmarks.
  - o Establish regional hubs for green practices and resource-sharing to centralize sustainability efforts.
- **Climate Resilience**:
  - o Construct infrastructure designed to withstand extreme weather conditions, such as floods or heatwaves.
  - o Integrate microgrids powered by renewable energy sources for greater energy independence.
- **Strengthening Public-Private Partnerships (PPPs)**:
  - o Encourage private investments in green projects through tax incentives.
  - o Promote research and development of innovative green solutions.

b. Expected Outcomes:

- Full adoption of sustainable practices.
- Alignment with the Sustainable Development Goals (SDGs) and international climate agreements.
- Uganda positioned as a model for sustainable data centre infrastructure in the east Africa region.

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